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PLATE I.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

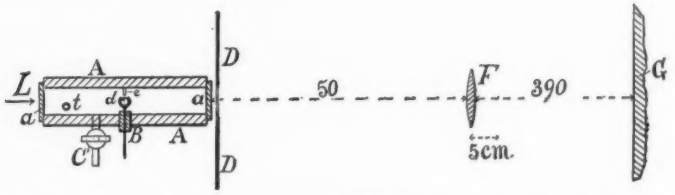
ART. I.—*The Lecture Experiment with Liquid Carbon Dioxide;* by C. BARUS.

THE well-known glass tubes containing liquid carbon dioxide are present in almost every laboratory; but the full experiment showing the passage of the liquid through the critical temperature is none the less difficult to perform satisfactorily to a class. This implies that the experiment should be made safely and that the progress of the whole phenomenon should be clearly exhibited in a reasonable time. I will, therefore, venture to describe the following method, which has given good results and has thrown light on certain moot questions aside from its immediate purpose.

The experiment should be made with sunlight, for this facilitates manipulation (the room need not be darkened), enables the student to follow the work throughout and simplifies the optic principles involved. Care should be taken to choose a tube not quite filled with liquid, even at the critical temperature; otherwise the meniscus is lost too soon near the end of the tube. When submerged in a water bath, the effective difference of refraction between liquid and gas is relatively slight and only an imperfect and dark image of the tube and the meniscus is obtained on projection. Most of the light is apparently totally reflected away from the screen. As a special experiment one may even show a tube partially filled with water, side by side with the carbon dioxide tube, the former on projection exhibiting a remarkably sharper contrast between liquid and gas than the latter.

Hence the phenomenon is to be shown by heating the tube in an air bath. In this case the projected image of the whole

CO_2 tube is clear, and the demarcation between liquid and vapor broad and unmistakable even at a distance. Moreover the tube acts like a cylindric lens, a sharp silvery focal line being obtained both for the liquid and the gaseous part. The two focal lines, however, are not coincident, and hence, the *projecting lens must be moved back and forth* to obtain sharp images of the linear foci corresponding to the vapor or the liquid, respectively. This motion is considerable, two or more inches with the usual tube; and inasmuch as the inner ends of both focal lines terminate on projection in the visible meniscus, I have based the following experiment on this observation:



The figure shows the disposition of apparatus in sectional plan through the middle of the (vertical) CO_2 tube. *AaAa* is a trough with vertical wooden sides *A A*, about a foot square and placed about 2 inches apart internally. The ends, through which sunlight *L* is to pass horizontally, are closed by strips of thick plate-glass *a*, *a*, and the non-conducting lid (not shown) is removable. The center of one of the wooden sides *A* contains a hole and receives the perforated cork B, in which a horizontal rod or axle suitably holding the carbon dioxide tube *d*, is free to rotate. The tube being thus revolable on a horizontal axis, the small viscosity of the liquid as compared with water is well shown in projection by inverting the tube rapidly. The millimeter scale *e*, on transparent glass, is fixed in the same vertical plane with the tube and projected with it to measure the expansion. A thermometer is placed at some point *t*. A wide stop-cock *C*, inserted near the bottom of the trough, allows the admission of either warm or cold air, or if need be, of water. The thermometer is only needed to calibrate the CO_2 tube and scale in terms of temperature, by using the trough as a common water-bath. After this, the thermometer may be dispensed with, since the tube and scale constitute a more sensitive and a more easily visible instrument.

D D is an opaque screen with an aperture small enough to cut off all rays except those which pass through the lens *F*. The latter was of about 55^{cm} focal distance, 10^{cm} in

diameter, and placed about 65^{cm} from the tube d, and about 390^{cm} from the white wall or screen G.

The whole experiment is, as stated, made in full daylight. The displacement of the lens F, when focusing the liquid or the vaporous column respectively, is fully 5^{cm} to 6^{cm}, and curiously enough the extreme positions of the lens remain practically unchanged with temperature.

To supply the trough with warm or cold air, a bellows may be used and the current passed through a coil of lead pipe contained in a water bath kept at the boiling point. The length of coil is easily regulated so that the available current of air enters the trough between 30° and 40° C. The extreme mobility of liquid CO_2 makes these relatively high and unequal temperatures harmless, for in a serious case the liquid merely simmers, boiling at the lower end of the tube, while the bubbles condense before they reach the surface. When no current of air passes, the air bath soon cools without special appliances.

The surprising part of the experiment, to me, is the observation that the marked displacement of the lens F, necessary to converge the linear foci of gas and of liquid, does not vary appreciably (i. e., in an experiment conducted like the above) with temperature; one would naturally suppose that the highly compressed gas and the liquid so near the point of continuously merging into the gas, would show similar refracting properties; one would, in other words, expect to find two linear foci, one corresponding to the compressed gas and the other to the liquid, at a distance apart which would gradually vanish as the critical temperature is approached. This means that the necessary displacement of the lens F would grow continually less, becoming zero at the critical temperature. Yet such is not at all the case, as the following data show:

Temperature:	17°	21°	23·5°	25·5°	27°	28°	29°
Column of gas left:	6	5	4	3	2	1	0^{cm}
Displacement of lens:	5·5	5·5	5·5	5·0	5·0	6·0	5·5

the error contained being the uncertainty of focusing.

The linear focus due to the liquid column is of course real, and in case of my tube (external diameter 0·75^{cm}, internal diameter unknown) lay about 3^{cm} in front of the tube.* (i. e.

* The theoretical treatment of this case is cumbersome, involving as it does an extensive consideration of caustics in view of the wide aperture. The following data, however, illustrate the final result for parallel rays. If tubes be taken about 0·6, 0·8, 1·2, 1·4, 2·6^{cm} diameter, and partially filled with water, the liquid focal line will as a rule lie within 1^{cm} in front of the nearer wall of the tube. The corresponding focus for the gaseous column will be equally sharp but virtual and lie about 3, 4, 6, 9, 30^{cm} respectively behind the liquid focal line, showing a

towards the screen *G*). The linear focus corresponding to the gas is however, virtual, for it is due to the refraction of a cylindrical shell of glass essentially of wide aperture, and lay about 3^{cm} behind the tube (i. e. away from the screen *G*).

Unfortunately the only tube available was too full of liquid CO_2, so that the liquid reached the top and could not be safely heated above 30° (critical temperature 31·1°); but I traced the total extinction of the gaseous focus, this being crowded out by the corresponding advance of the liquid focus quite into the top of the spherical end of the tube.

As soon as I get another tube I hope to push this experiment through to a definite conclusion. As far as I have gone, there seems to be small probability for the occurrence of real continuity between CO_2 gas and CO_2 liquid at the critical temperature. There is continuity between the liquid and *a gas which preserves the same molecule*, the same molecular structure as the liquid from which it issues. Doubtless at still higher temperatures the gas with the liquid molecule will break up into the true gas with the gaseous molecule, and the fact should be indicated by the sliding lens method sketched in the above experiment.

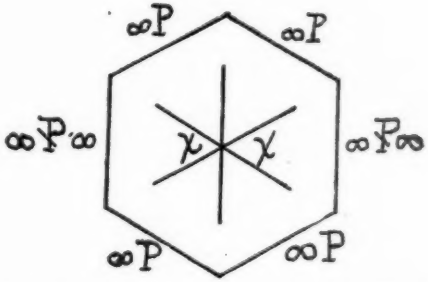
Finally it is desirable to specify a superior limit for the molecular weight of the liquid in question. The critical volume of carbon dioxide referred to the normal gas (0° C., 76^{cm}) is ·0043 (Cailletet verified by Sarrau). Thus the vapor density is 4·3 and the molecular weight by Avogadro's law, 123. This is singularly near C_3O_6, whose molecular weight is 132. The question thus arises whether C_3O_6 gas above the critical temperature may not be as justly treated as a gas, as any other vapor under the ordinary conditions of vapor density measurement: for one may argue that the *intermolecular* forces which cause divergence from Boyle's law, etc., in CO_2 gas at the critical point, have in C_3O_6 gas become *intramolecular*, giving the new molecule greater freedom of motion. In such a case C_3O_6 would be the molecule of liquid carbon dioxide.

rapid march toward infinity. As in the above CO_2 tube, the liquid focus lay about 3^{cm} ahead of the tube, the smaller refraction of this liquid is manifest, but so far as can be detected by the lens method, the gas focus does not appreciably differ in position from the gas focus for atmospheric air.

Brown University, Providence, R. I.

ART. II.—*Observations on Percussion Figures on Cleavage plates of Mica;* by T. L. WALKER, Leipsic.

REUSCH* discovered that when a sharp-pointed punch is placed on a thin plate of mica and struck a sharp blow with a small hammer, a six-rayed star is formed on the mica plate. He also observed that one of the three lines forming the star is parallel to the clinopinacoid. The other two lines he described as parallel to the prismatic edges of the six-sided cleavage fragment of mica. These observations were confirmed and the investigation extended by Bauer,† who recommended the use of a large, somewhat blunted needle instead of the blunter instrument used by Reusch. He also emphasized the importance of the nature of the foundation on which the mica rests when the needle is struck. Reusch recommended a glass plate covered with a thin sheet of vulcanite. The accompanying figure represents a basal section of a mica crystal and indicates the directions of the different rays of the percussion figure.



These figures are fully described in all the larger text-books on Mineralogy, and although they all agree in asserting that two of the lines forming the star are parallel to the prismatic edges of the basal section, I find as a result of a large number of measurements that this is seldom if ever the case.

Since the prismatic faces of the micas form an angle varying only a few minutes from 120°, we would expect that all the rays of the percussion figure would form angles very nearly 60°. By measuring the angles in percussion figures of different micas great variations were observed. The following table shows measurements for about twenty specimens representing all the commoner species of mica and from widely

* Reusch, Ber. Ak. Berlin, 428, July 9th, 1868.
† Pogg. Ann., 1869; also Zeitsch d. d. g. Gesellschaft, 1874.

separated localities. The letter χ is used to designate the angle opposite the clinopinacoidal edge. The numbers given are averages of about half a dozen measurements in each case.

		Optical plane.					χ
1.	*Muscovite*—	$\perp\infty$ P∞	(mica,	1st kind),		Murray Bay, P. Q. Canada	=52° 53′
2.	"	"	"	"	"	Acworth, N. H., U. S. A.	=53° 20′
3.	"	"	"	"	"	Locality unknown.	=53° 42′
4.	"	"	"	"	"	Hereroland, S. W. Africa	=54° 32′
5.	"	"	"	"	"	Peterboro Co., Ontario	=54° 56′
6.	"	"	"	"	"	Marienberg, Saxony	55° 32′
7.	"	"	"	"	"	Utö, Sweden	55° 57′
8.	*Lepidolite*—	"	"	"	"	Wolkenburg, Saxony	59° 12′
9.	"	$\parallel$	"	("	2d kind)	Perm, Russia	59° 07′
10.	"	"	"	"	"	Penig, Saxony	59° 45′
11.	"	"	"	"	"	Mursinsk, Urals	60° 16′
12.	*Zinnwaldite*—	"	"	"	"	Zinnwald, Saxony	59° 12′
13.	*Biotite*—	$\perp$	"	"	"	Arendal, Norway	practically 60°
14.	"	"	"	"	"	Siberia	"
15.	*Magnesiaglimmer** (Anomite ?)	"	"	"		Lake Baikal	
16.	*Phlogopite*—	"	"	"	"	Radigara, Ceylon	60° 52′
17.	"	"	"	"	"	South Burgess, Ont.	61° 53′
18.	"	"	"	"	"	Radigara, Ceylon	62° 27′
19.	"	"	"	"	"	Radigara, Ceylon	63° 28′

The above table shows that the angle χ varies from 52° 53′ in muscovite from Murray Bay, Canada, to 63° 28′ in phlogopite from Radigara, Ceylon. It is noteworthy that all the micas examined, when arranged in a series according to the magnitude of the angle χ, then all the muscovites are together in one group which is quite separated from all the other micas; then follow the lithia micas in a second group, the biotites in a third and finally the phlogopites. We notice, however, that in this respect, the lepidolites and zinnwaldites form only one group, though generally regarded as distinct species. Possibly such measurements as the above may be found useful in the determination and classification of micas. No measurements have been made of paragonite, lepidomelane or anomite. In these species it may be different to obtain figures on which satisfactory measurements could be made.

The figures were produced with a large blunt darning needle. The smooth back of a small book formed a satisfactory foundation. Frequently after producing the figures on a somewhat thick sheet of mica, one may obtain good material for measurements by separating a very thin film from the bottom of the plate.

The so-called pressure figures, which are caused in mica plates by application of gradual pressure, using a slightly

* Too dark and brittle for observation.

rounded punch, are generally described as consisting of rays forming with one another angles of very nearly 60°, and at right angles to the rays of the above-mentioned percussion figures. In the asterism of Canadian phlogopites, the rays of this star-phenomenon are said to have the same direction as the rays of the pressure figures. It would be interesting to know whether the rays of the pressure figures do really meet at angles of 60° or whether they are at right angles to the rays of the percussion figures. That they cannot be both, is clear from the above observations. The angle χ probably varies slightly with the temperature of the plate on which the figures are made.

Leipsic, Jan. 24th, 1896.

Art. III. — *The Seven Day Weather Period;* by H. Helm Clayton.

In this Journal, vol. xlvii, March, 1894, data were presented by the writer to show the existence in the United States of six and seven day periods or rhythms in the weather which apparently resulted from, or caused, a certain regularity in the movements of high and low pressure areas across the country.

To enable the investigation to be extended into other countries and embrace as large a part of the world as possible, the trustees of the Elizabeth Thompson fund allowed a grant of 200 dollars. This admitted of obtaining the assistance of Mr. Arthur Sweetland in the reductions.

Mr. A. Lawrence Rotch freely allowed the use of the large amount of observational data in his possession collected from all parts of the world, and by permitting the investigation to proceed as a part of the work of the Blue Hill Meteorological Observatory he made the completed results possible.

For the purpose of this research three stations were selected in the arctic region, four in the United States, five in Europe, two in Asia, two in Oceanica near the equator, three in middle South America, one in Mauritius, and one in Australia.

The work embraced the investigation of a weather period of 7 days 6·43 hours, another of 6 days 3·95 hours, and a third of 5 days 10·8 hours. The methods and results were in each case similar, and it is deemed necessary to recite in detail only those obtained for the first period. Beginning with January, 1880, an ephemeris was constructed for the 15 years ending

with Jan. 6, 11·7 P. M., 1896, which may be taken as the epoch. For each of the selected stations, during the entire time covered by available observations, the number of barometric minima which occurred on each day of the seven day period was counted. The first day consisted of the first 24 hours following the dates of the ephemeris, the second day consisted of the succeeding 24 hours, and so on for the seven days, the final quarter day being omitted. The number of barometric minima occurring on each day was selected because it is generally recognized by meteorologists that rain, temperature changes, etc., cluster around the barometric minima, and any periodicity discoverable in these minima implies a periodicity in all the other weather changes. The number of barometric minima observed on each day of the period at each of the stations selected is given in Table I, in which the days of maximum frequency are shown by the heavy-faced type.

TABLE I.

				Day of Period.						
UNITED STATES.	Lat.	Long.	Years.	1	2	3	4	5	6	7
Roseburg,	43° 13′ N.	123° 20′ W.	1885–93	97	98	82	**100**	98	**100**	98
Cheyenne,	41 8	104 48	1885–93	113	96	108	**109**	103	106	**120**
Chicago,	41 52	83 38	1885–93	87	**127**	89	96	106	**123**	96
Blue Hill,	42 12	71 6	1884–93	121	97	**150**	128	120	109	**153**
EUROPE.										
Perpignan,	42° 42′ N.	0° 33′ E.	1880–90	**120**	120	117	107	**117**	97	99
Lesina,	43 10	16 27	1883–91	68	**83**	64	69	**72**	58	**74**
Bucharest,	44 25	26 46	1885–91	**78**	45	60	**69**	62	55	48
Christiania,	59 55	10 43	1888–92	**51**	41	44	**59**	47	**51**	43
St. Petersburg,	59 56	30 16	1885–90	57	**59**	39	61	**65**	57	**67**
ARCTIC REGION.										
Point Barrow,	71° 27′ N.	156° 15′ W.	1881–83	11	12	12	11	**17**	10	13
Fort Conger.	81 44	64 45	1881–83	**17**	11	8	**18**	10	11	17
Ekholm,	78 28	15 40	1882–83	**10**	8	**10**	4	9	7	5
ASIA.										
Zi Ka Wei,	31° 11′ N.	121° 23′ E.	1885–92	41	49	**57**	39	53	52	**54**
Tokio,	35 41	139 46	1885–86 1890–93	**75**	65	65	**68**	67	58	66
OCEANICA.										
Manilla,	14° 35′ N.	120° 59′ E.	1890–91	**26**	21	21	21	17	19	19
Batavia,	6 11 S.	106 50	1881–92	91	110	76	107	100	**106**	99
SOUTH AMERICA.										
Matanzas,	34° 48′ S.	58° 37′ W.	1880–89	89	84	**100**	83	81	81	**100**
Corrientes,	27 28	58 45	1881–89	66	70	**77**	75	66	**68**	63
Rio Janeiro,	22 20	43 55	1883–91	**54**	38	**50**	44	48	**51**	45
AFRICA.										
Mauritius,	20° 5′ S.	57° 30′ E.	1887–92	31	33	39	39	**40**	32	34
AUSTRALIA.										
Flagstaff,	37° 48′ S.	143° 45′ E.	1889–92	**39**	28	**36**	33	28	27	35

The results show that in general there are two maxima and two mimima of frequency during the seven days, and at some stations there appear to be three. If the positions of maximum frequency at each station are determined by constantly acting causes, it is to be expected that when the time covered by observations is divided into shorter intervals the maxima would tend to occur on the same days of the period provided the intervals are not too short. At all stations where the observations were available for a time long enough to permit it, they were separated into groups of three years, and the frequency of barometric minima was determined for each day of the seven day period in each group. Groups of ten years would have been better had the observations been for a long enough time to permit them. The results are given in Table II for a few stations scattered as widely as possible, the maxima being indicated as before by heavy-faced type.

TABLE II.

Station.	Years.	Day of Period. 1	2	3	4	5	6	7
Chicago,	1885–87	24	**35**	24	25	36	**37**	34
	1888–90	25	**46**	29	38	28	**43**	28
	1891–93	38	**46**	36	33	42	**43**	34
Perpignan,	1880–83	**47**	46	45	**49**	46	29	40
	1884–86	**36**	27	32	**35**	31	29	20
	1887–90	37	**47**	40	23	**40**	39	39
Zi Ka Wei,	'85, '88, '89,	21	31	**37**	23	**38**	27	**38**
	1890, '92	20	18	**20**	16	15	25	**26**
Batavia,	1881–83	16	**25**	22	21	23	**30**	23
	1884–86	23	**30**	18	24	19	**26**	26
	1887–89	27	**27**	14	29	**30**	20	23
	1890–92	25	**28**	22	**33**	28	**30**	26
Matanzas,	1880–83	34	34	**38**	34	30	34	**49**
	1884–86	28	**31**	28	22	**30**	18	21
	1887–89	27	19	**34**	27	21	29	**30**

These stations are those which have the longest series of available observations, and the results show that all over the world the days of the period on which the maximum frequency of barometric minima occurs at any station tend to remain the same at that station during succeeding years.

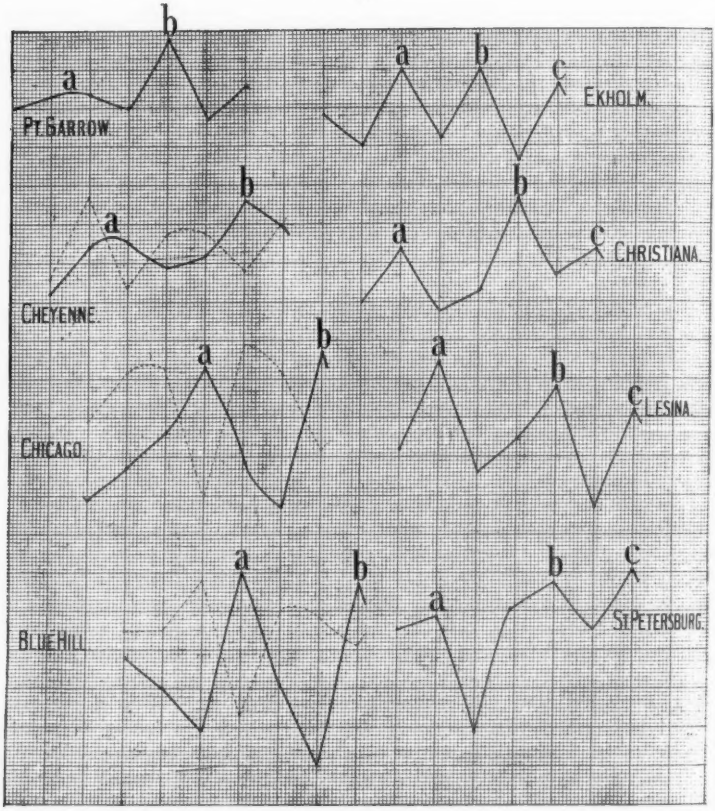
The results in Table I were plotted in curves and studied from two different standpoints:—

(1) Stations near the same latitude but differing in longitude were plotted under one another to see what relation existed between adjacent stations.

(2) Stations near the same longitude but differing in latitude were plotted under one another for the same purpose. The results for adjacent stations showed that the days of maximum

frequency occurred first at higher latitudes and at western stations, indicating that the periodicity was connected with barometric waves which swept from the poles toward the equator and from west to east, or in other words from the northwest.

1.

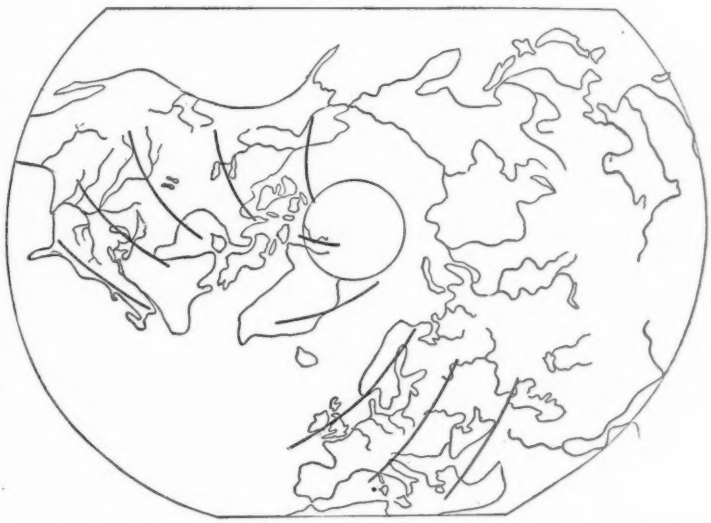


Beginning in the arctic region, the results for several successive stations lying in a general N.W. to S.E. direction are plotted in diagram 1 for both Europe and America. The beginnings of the curves are displaced one day for each successive difference of about 15° of longitude or latitude so as to show the corresponding points of the curves. The American stations are Pt. Barrow, Cheyenne, Chicago, and Blue Hill,

and the European stations Ekholm, Christiania, Lesina, and St. Petersburg. The curves seem to indicate very clearly in the average that twice in a period of 7 days 6·43 hours in America, and three times in Europe, waves of barometric minima, or storms, tend to begin near the poles and sweep across the continents.

The day of the period in which occurred the maximum *b*, shown in diagram 1, was plotted on a map for each station in Europe and America. The heavy lines in diagram 2 show the position of the maximum storm frequency for each suc-

2.



cessive day. It is seen that the first line in America passes through Pt. Barrow on the extreme northern coast; two days later it passes through Cheyenne in the central United States and two days later through Blue Hill on the Atlantic coast. In Europe it first passes through Ekholm near the arctic circle east of Greenland; a day later it passes through Christiania in southern Norway; a day later, through St. Petersburg in northern, and Lesina in southern Europe, and a day later over Bucharest near the Black Sea.

To determine whether these days of maximum storm frequency remained the same at each station throughout the year or changed with the seasons, the observations at each station were divided into four seasons, namely: December to February, March to May, June to August, and September to

November, and storm frequencies were determined for each day of the seven day period. The results for a few stations, separated as widely as possible, are given in Table III.

TABLE III.

	Day of Period.						
Chicago,	1	2	3	4	5	6	7
December–February,	23	**33**	27	26	23	**39**	26
March–May,	22	**35**	22	25	**34**	23	22
June–August,	18	22	16	23	22	**30**	23
September–November,	24	**37**	24	27	27	**31**	25
Bucharest,	7	1	2	3	4	5	6
December–February,	13	**18**	12	8	**20**	13	16
March–May,	10	**23**	9	**20**	17	18	15
June–August,	12	**20**	10	16	15	**18**	12
September–November,	13	**17**	14	16	**17**	13	12
Zi Ka Wei,	2	3	4	5	6	7	1
December–February,	12	**12**	10	10	**14**	14	5
March–May,	16	**17**	14	14	14	**17**	15
June–August,	12	**12**	6	**14**	9	10	9
September–November,	9	**16**	9	15	**15**	5	12
Batavia,	1	2	3	4	5	6	7
December–February,	21	**24**	19	**28**	17	24	**30**
March–May,	25	**26**	20	24	23	**28**	24
June–August,	17	**26**	17	26	**28**	14	22
September–November,	28	**34**	20	29	32	**40**	22
Matanzas,	2	3	4	5	6	7	1
December–February,	17	**23**	22	16	16	**26**	26
March–May,	19	**27**	24	22	23	23	**24**
June–August,	25	**27**	15	**23**	22	20	20
September–November,	23	**23**	22	20	20	**30**	19
Flagstaff,	7	1	2	3	4	5	6
December–February,	**9**	7	8	7	**9**	6	9
March–May,	7	**10**	8	7	8	**9**	8
June–August,	10	**11**	6	8	**8**	7	1
September–November,	9	**11**	6	**14**	7	6	9

The data in the table are so arranged that what appear to be corresponding days at all the stations come under one another, the day of the period being given above the data for each station.

The heavy-faced figures showing the maxima render it apparent that there is a tendency at every station for the days of maximum frequency to remain on the same days of the period throughout the year. Thus at Chicago the maxima tend to occur on the second and between the fifth and sixth day of the period; at Bucharest they tend to occur on the first and between the fourth and fifth day of the period, etc.

If, however, the curves are plotted they show considerable irregularities and dissimilarities. Smoother and more com-

parable results are found by allowing for the drift of the barometric waves as previously found and adding several stations together. Thus the results for Cheyenne are added to those found one day later at Chicago and these to those found one day later at Blue Hill. In this way a larger number of observations is obtained and local influences are eliminated. In the same way, allowing one day between each station, the results for Lesina, Bucharest, and Perpignan, are added together. Those for Zi Ka Wei and Tokio and for Batavia and Manila are added with one day between, and those for Matanzas, Corrientes and Rio Janeiro are added together, allowing one day between the last and first two stations. The results are given in Table IV under the headings of United States, Europe, Asia, Oceanica and South America, and are shown in diagram 3.

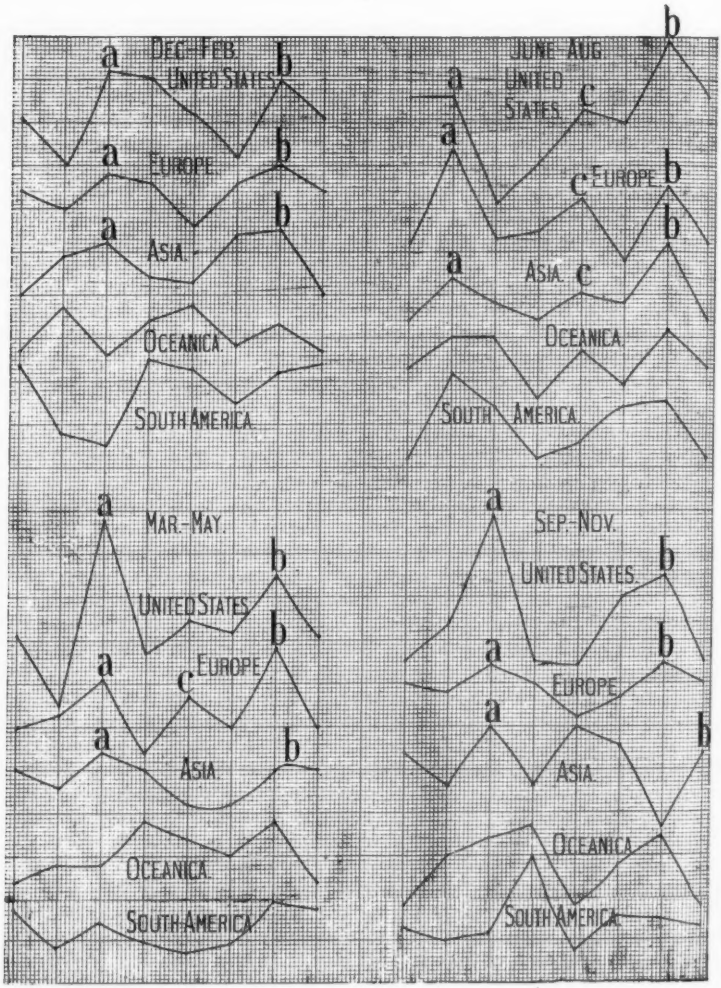
TABLE IV.

	Day of Period.						
United States,	1	2	3	4	5	6	7
December–February,	82	**100**	91	80	**102**	100	92
March–May,	82	**95**	81	64	**108**	77	85*
June–August,	70	**89**	76	**76**	51	61	73*
September–November,	90	**95**	75	84	**109**	75	74
Europe.							
December–February,	61	**64**	58	54	**62**	60	50
March–May,	60	**78**	60	64	**71**	54	67*
June–August,	48	**65**	52	**74**	53	54	62*
September–November,	57	**65**	60	58	**64**	60	52
Asia.							
December–February,	34	**35**	20	29	**32**	24	23
March–May,	31	**35**	35	33	**37**	35	31
June–August,	22	**29**	20	**25**	22	20	23*
September–November,	32	22	31	27	**34**	27	**34**
Oceanica.							
December–February,	24	**29**	23	**33**	22	30	**34**
March–May,	32	**36**	29	31	31	**36**	34
June–August,	19	**32**	23	**30**	30	16	27*
September–November,	32	**39**	22	34	38	**41**	22
South America.							
December–February,	45	52	**54**	38	35	**55**	53
March–May,	49	**59**	57	48	**54**	50	47
June–August,	**54**	**55**	42	**62**	34	42	46
September–November,	56	**55**	53	50	51	**70**	47

The "Day of Period" at the top of Table IV has no further significance than for use in reference. The curves in diagram 3 begin on the third day of the table as arranged above. These curves, at least for the northern hemisphere, show a marked similarity for the same season in different countries. In winter there are two maxima of storm frequency, marked *a* and *b* in the diagram; in spring a slight

tertiary maximum marked *c* shows itself in Europe and the United States. This third maximum becomes general over the

3.



northern hemisphere in summer. In autumn the double maximum again becomes predominant. In Oceanica nearly under the equator there appears to be a tendency to three maxima in

the frequency of barometric minima except from September to November.

In South America only two maxima appear, but the positions of the maxima tend to vary simultaneously with those in the northern hemisphere, and thus add some support to the hypothesis that the causes of variation in the period are cosmical and not seasonal.

As a further investigation the number of barometric maxima occurring on each day of the period was counted for all the above mentioned stations in Europe and the United States. The results show, with only one or two slight exceptions, the greatest frequency of barometric maxima about half way between the barometric minima, and when the two are plotted together they show similar, but reversed, curves. Since this result is perhaps what was naturally to be expected, the tabular matter is omitted here, but the results for Cheyenne, Chicago, and Blue Hill are plotted in diagram 1 by means of dotted lines over the continuous curves which show the frequency of barometric minima.

To ascertain to what extent the period would show itself in short intervals, the periods were separated into groups of eleven periods occupying about eleven weeks each, and the barometer observations taken three times a day at Blue Hill Observatory were averaged for each eight hours of the period from 1890 to 1895. The results for 1890 were the most marked and are given below, though I think the results for each year sufficiently confirm the existence of the period. The dates in this table are the dates of the beginning of each group.

TABLE V.

Day	1			2			3			4			5			6			7		
Bar. 29·+ inch																					
Jan. 3	35	42	45	49	52	49	43	33	29	**24**	27	31	31	29	28	33	32	27	**18**	20	26
Mar. 16	24	32	36	38	35	30	22	**20**	22	24	27	31	30	26	28	31	29	27	23	**22**	24
June 4	29	30	31	29	29	**29**	32	33	36	39	41	42	41	39	37	34	29	28	25	**23**	27
Aug. 23	27	29	32	34	31	**28**	38	41	42	41	29	**28**	31	32	31	26	20	17	**16**	19	22
Oct. 6	12	12	12	19	20	28	37	41	42	32	22	18	19	26	31	27	21	15	09	12	14

It will be seen from Table V that the chief minimum remained persistent on the seventh day. The secondary minimum moved forward from the beginning of the fourth day in winter to the end of the second day in the period in summer, and toward the end of summer showed a double minimum, one on the second, and the other on the fourth day. In autumn and early winter the minima are again on the fourth and the seventh

day. Hence the average lowest pressure, even for short intervals during 1890, occurred on exactly the same days of the period as the greatest frequency of barometric minima during the ten years' observation. The period was less marked during subsequent years and longer intervals are required to show the same persistency.

To determine the relation of the period to temperature changes at Blue Hill, the departures from the normal temperatures were determined for each day during 1887 and 1888 at 8 A. M. and 8 P. M. These were then arranged in seven day periods and averaged. The results in the following table show the departures from the mean or normal of the two years:

TABLE VI.

Day	1	2	3	4	5	6	7
Dep.	−1·0—1·2	−0·7 + 0·0	+ 0·5 + 0·2	−0·1 − 0·4	−0·1 + 0·7	+ 1·3 + 0·7	−0·1 − 0·9

The results show the greatest plus departures on the third and the sixth day, or about one day preceding the lowest mean barometric pressures, with the extremes of the temperature and pressure departures on the sixth and the seventh day respectively. The greatest minus temperature departures are found on the first and the fourth day, with the lowest mean temperature on the first.

It must be evident to every one who accepts these investigations that a promising and important field is here presented for weather forecasting. As yet we are confined to averages in forecasting. An effort to follow and separate the individual periods has been attended with only a slight success.

It is possible to say that in all parts of the world barometric minima will be from 10 to 20 per cent more frequent on certain days than on certain other days, provided the interval taken is sufficiently long. It is also possible to say that certain days will average colder than other days. I think even this information would prove of value to certain industries, and I have an abiding faith that it is only the beginning of the science of weather forecasting which is yet to come.

ART. IV.—*On Pearceite, a Sulpharsenite of Silver and on the Crystallization of Polybasite;* by S. L. PENFIELD.

1. *Pearceite.*

THE mineral to be described as pearceite in the present article is a sulpharsenite of silver, Ag_9AsS_6 or $9Ag_2S$, As_2S_3, analogous to polybasite Ag_9SbS_6, and like the latter characterized by having a part of the silver replaced by copper and often by small quantities of zinc and iron. It can not be claimed to be a *new mineral*, for as an arsenical variety of polybasite it has previously been recognized although no special name has been assigned to it. H. Rose* first described polybasite and gave the name to the species in 1828, and in 1833 he published† an analysis of a specimen from Schemnitz containing arsenic, with only a trace of antimony, while in the original polybasite from Durango, Mexico, described by him, both antimony and arsenic were present, and he recognized the fact that these elements were isomorphous and could mutually replace one another. The polybasites from Durango in Mexico, Freiberg in Saxony, Pribram in Bohemia, the Two Sisters' mine near Georgetown, the Yankee Boy mine near Ouray, and the Sheridan mine near Telluride in Colorado, the Comstock Lode in Nevada, and apparently from most localities, are essentially the antimony variety, and in mineralogical literature the composition of polybasite is usually given as a *sulphantimonite* of silver. Rammelsberg‡ gives an analysis by Joy of polybasite from Cornwall, England, where antimony and arsenic are present in about equal molecular proportions, and the author in connection with Mr. Stanley H. Pearce, has published§ analyses of arsenical polybasite (*pearceite*) from the Mollie Gibson mine, Aspen, Colorado. This latter material was not distinctly crystallized, but was found in great quantity and was the mineral which carried the bulk of the silver in the most productive silver mine in Colorado at that time.

The author's attention has recently been called to the occurrence of beautifully crystallized pearceite, or arsenical polybasite from the Drumlummon mine, Marysville, Lewis and Clarke Co., Montana. The mineral was first sent by Mr. R. F. Bayliss, of the Montana Mining Co., to Dr. Richard Pearce, of Denver, with the request that it should be investigated, and

* Pogg. Ann., xv, p. 573, 1829.
† Loc. cit.. xxviii, p. 56, 1833.
‡ Mineralchemie, p. 102, 1860.
§ This Journal, xliv, p. 15, 1892.

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the following analysis was made by Mr. F. C. Knight under Dr. Pearce's immediate supervision.

	Found.		Ratio.		Theoretical composition where $Ag_2 : Cu_2 : Fe = 255 : 143 : 19$.
S	17·71 ÷ 32	= ·553		11·95	17·96
As	7·39 ÷ 75	= ·098		2·11	7·02
Ag	55·17 ÷ 216	= ·255	·417	9·00	55·61
Cu	18·11 ÷ 127	= ·143			18·34
Fe	1·05 ÷ 56	= ·019			1·07
Insol.	·42				
	99·85				100·00

Dr. Pearce recognized that the mineral belonged to the polybasite class, where arsenic played the role usually taken by antimony, and forwarded the specimens, together with the analysis, to the author for an expression of opinion. As may be seen from the ratio, the proportion of $S : As : (Ag_2 + Cu_2 + Fe)$ is very nearly $12 : 2 : 9$, which is that demanded by the polybasite formula, and taking the metals in the same proportion as they are found in the analysis, $Ag_2 : Cu_2 : Fe = 255 : 143 : 19$, and calculating the theoretical composition, results agreeing very satisfactorily with the analysis are obtained.

Although recognizing that antimony and arsenic are isomorphous and may mutually replace one another, it is customary and has been found convenient in mineralogy to consider the sulphantimonites and sulpharsenites as distinct species, and to designate them by different names, and the author proposes that hereafter the name polybasite shall be restricted to the antimony compound Ag_9SbS_6, and to make of the corresponding arsenic compound Ag_9AsS_6 a distinct species. For the arsenical mineral he takes pleasure in proposing the name *pearceite* as a compliment to his friend, Dr. Richard Pearce, of Denver, whose keen interest in mineralogy and connection with one of the large smelting and refining works of Colorado have made him known both to scientific men and to those interested in the development of the mining industries of the Rocky Mountain region. The author furthermore takes pleasure in expressing his thanks to Mr. Bayliss, who has taken a great interest in the investigation and naming of the mineral, and has most generously placed at his disposal all of the available material.

It seems best to give at this point the analyses of pearceite, already referred to, which have previously been published as arsenical varieties of polybasite. In the theoretical composition given with each the ratio of the metals is the same as in the accompanying analysis.

I. H. Rose, $Ag_2 : Cu_2 : Zn : Fe = 335 : 24 : 9 : 6$.
II. Penfield, after deducting 12·81 per cent of impurities, mostly PbS, $Ag_2 : Cu_2 : Zn = 263 : 117 : 43$.
III. S. H. Pearce, after deducting 28·18 per cent of impurities, mostly PbS, $Ag_2 : Cu : Zn = 276 : 102 : 49$.

	I.		II.		III.		Theory for
	Schemnitz.	Theory.	Aspen, Colo.	Theory.	Aspen.	Theory.	Ag_9AsS_6.
S.	16·83	16·19	18·13	18·13	17·73	18·02	15·50
As	6·23	6·32	7·01	7·08	6·29	7·03	6·05
Sb	0·25	....	·30	....	0·18	....	....
Ag	72·43	73·47	56·90	57·07	59·73	59·06	78·45
Cu	3·04	3·08	14·85	14·91	12·91	12·77	....
Zn	0·59	0·60	2·81	2·81	3·16	3·12	....
Fe	0·33	0·34	....	....	....	....	....
	99·70	100·00	100·00	100·00	100·00	100·00	100·00

Crystallization.

The crystallization of pearceite is *monoclinic* but with a close approximation to rhombohedral symmetry. The habit is commonly hexagonal with the basal planes prominent and the zones of bevelling forms between them often highly modified. The material from which crystallographic data could be obtained came wholly from a single specimen where the crystals were implanted upon a gangue of quartz and imbedded in calcite, and were obtained by dissolving the latter in dilute acid. Unfortunately the crystals had grown close together, thus interfering more or less with one another, and they also were cracked, probably owing to the severe shocks received in the processes of blasting and mining; consequently when liberated by dissolving the calcite they fell to pieces, so that usually only parts of crystals were available for measurement. The faces had a beautiful metallic luster, and when free from striations and vicinal planes gave excellent reflections on the goniometer. The determination of the crystalline form and the axial ratio proved to be a difficult matter owing to the fragmentary character of the crystals, their grouping, often in nearly parallel position, a probable twinning and their close approximation to rhombohedral symmetry, and it was not until many measurements had been made upon a series of crystals that a satisfactory solution of the problem was obtained.

As fundamental measurements, the following were selected:

$$m \wedge m,\ 110 \wedge \bar{1}10 = 60°\ 2'$$
$$c \wedge d,\ 001 \wedge 102 = 25\ \ 3$$
$$c \wedge a,\ 001 \wedge 100 = 89\ \ 51$$

from which the axial ratio was calculated:

$$a : b : c = 1{\cdot}7309 : 1 : 1{\cdot}6199$$
$$\beta = 001 \wedge 100 = 89° 51'.$$

The crystals are quite highly modified, and it seems best before giving a list of the forms to explain the different kinds which were observed and to state something concerning their occurrence. The basal pinacoid *c*, 001 is prominent, is hexagonal or triangular in shape, and is characterized by triangular markings and vicinal planes, fig. 1, so that it was often impossible to obtain accurate measurements from it. The prism *m*, 110 and the pinacoid *a*, 100 are nearly at right angles to *c* and 60° from one another, so that the combination approaches very closely to an hexagonal prism, and it is sometimes impossible to distinguish *a* from *m*, or without accurate measurements to decide whether the forms between *c* and *a* or *c* and *m* modify the acute or obtuse angles. It is very probable that a twinning is present, similar to that of the micas and chlorites, where the twinning plane is at right angles to *c* in the zone $m \wedge c$ and where the parts are superimposed upon one another with *c* as the composition face, but no absolute proof of this was obtained. The crystals are opaque, so that optical tests could not be applied as was done by Miers,* who has described this kind of twinning on polybasite. If the twinning occurs on pearceite, as it probably does, it must cause uncertainty as to the identification of some of the forms in the zones between *c* and *a* and *c* and *m*, and it may also account in part for the decidedly rhombohedral aspect of many of the crystals. As far as could be observed, similar faces are often developed about equally above and below *m* and *a* in the zones between the basal planes, but to what extent this is due to twinning it is impossible to state. The faces in these zones are moreover commonly striated parallel to their mutual intersection, and while *r* and *p*, r° and p°, *n* and *t* and n° and t° (compare fig. 1 and the list of forms beyond), are the most prominent, other faces, especially *e* and e°, *f* and f°, *s* and s° and *u* and u°, are very often present. When *q* was observed it was always a prominent, dull face, not sharing in the horizontal striations of the other faces of the zone. It was only occasionally that forms were observed between *c*, 001 and *l*, 310, and they were always small, while the corresponding forms were not observed between 001 and $\bar{3}10$. The pinacoid *b*, 010 was identified, not only by the symmetrical arrangement of the forms with reference to it, but also by the similarity of the angles measured

* Min. Mag., viii, p. 204, 1889.

from it on to similar adjacent forms. The prism *l*, 310 is often developed about equal in size to *b*, and with the latter would correspond in rhombohedral symmetry to a hexagonal prism of the second order. The prism *h*, 130 and the horizontal prism *k*, 021 were found together on only one crystal as small faces symmetrically located with reference to the pinacoid *b*.

1. 2.

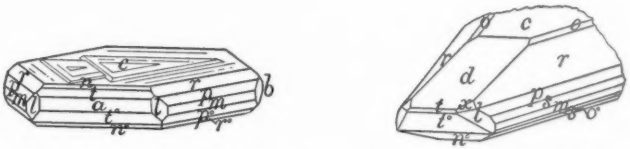


Fig. 1 shows the prevailing type of crystal, with hexagonal aspect, the characteristic triangular markings on the basal plane, but with only the most prominent of the bevelling faces present. Two fragments were found which in habit were essentially like fig. 2. These had a decidedly monoclinic habit and were the most free from striations, vicinal faces and indications of a possible twinning of any crystals that were observed, and from them the fundamental measurements previously given were obtained.

A few crystals were quite remarkable for their size, the hexagonal plates being 3^{cm} in diameter and 1^{cm} thick, but they were coated with druzy quartz and could not be used for crystallographic measurement. The specimen showing the largest crystals was presented by Mr. Bayliss to the author for the Brush collection at New Haven. The crystals from which the measurements were obtained averaged less than 4^{mm} in diameter.

The following list includes the forms which have been observed, but, as already stated, twinning may account for a similar form being found modifying both the acute and obtuse angles of the crystals and being repeated in the zones between *c* and *a* and *c* and *m*.

a, 100	*d*, 102	*t*°, $\bar{5}01$	*s*, 221	*s*°, $\bar{5}21$
b, 010	*n*, 101	*e*°, $\bar{4}01$	*u*, 331	*u*°, $\bar{5}31$
c, 001	*t*, 201	*f*°, $\bar{6}01$	*o*°, $\bar{1}14$	*x*, 311
l, 310	*e*, 401	*o*, 114	*q*°, $\bar{1}13$	*y*, 313
m, 110	*f*, 601	*r*, 112	*r*°, $\bar{1}12$	*z*, 31·12
h, 130	*Δ*, $\bar{2}03$	*p*, 111	*p*°, $\bar{1}11$	
k, 021	*n*°, $\bar{1}01$	*v*, 332	*v*°, $\bar{3}32$	

The forms corresponding to these found by Miers* on polybasite are *c*, *m*, *n*, *t*, *p*, *s*, *r* and *w*, 109.

* Loc. cit.

The following table of measured angles includes a series which was selected wholly on account of the character of the reflections, due to the freedom of the faces from striations and other disturbing influences. They were mostly made on the two fragmentary crystals, already mentioned, having a habit like fig. 2, and where several measurements are given they represent independent ones in different zones or on different crystals. As may be seen, the measured angles show a fairly good agreement with the calculated values, and it may, therefore, be assumed that the axial ratio has been determined with a fair degree of accuracy.

	Calculated,	Measured.		
$c \wedge a$, 001∧100	89° 51′	89° 51′*,	89° 49′	
$c \wedge l$, 001∧310	89 52	89 48,	89 54	
$c \wedge m$, 001∧110	89 55½	89 55		
$m \wedge m$, 110∧$\bar{1}$10	60 2	60 2*		
$b \wedge m$, 010∧110	30 1	30 1,	30 1	
$a \wedge l$, 100∧310	29 59	29 58,	29 57¼	
$b \wedge h$, 010∧130	10 54	10 53		
$b \wedge k$, 010∧021	17 9	17 5		
$c \wedge d$, 001∧102	25 3	25 3*,	25 2½	
$c \wedge n$, 001∧101	43 2	43 4,	43 5	
$c \wedge e^{\circ}$, 001∧40$\bar{1}$	104 49	104 53½		
$c \wedge t^{\circ}$, 001∧20$\bar{1}$	118 00	117 56		
$c \wedge n^{\circ}$, 001∧10$\bar{1}$	136 49½	136 52½		
$c \wedge r$, 001∧112	43 3	43 3,	43 6	
$c \wedge p$, 001∧111	61 49	61 56	43 0	
$d \wedge r$, 102∧112	36 14	36 12,	36 16	
$b \wedge p$, 010∧111	40 15	40 12,	40 12	
$b \wedge p^{\circ}$, 010∧$\bar{1}$11	40 10½	40 8		
$b \wedge s$, 010∧221	33 12	33 12		
$c \wedge y$, 001∧313	47 9	47 10,	47 7	

In the following table the calculated angles of most of the faces on to the basal plane are given, arranged so as to show the slight variation from one another and from rhombohedral symmetry of the forms d, o and o°; Δ and q°; n, r, n° and r°; t, p, t° and p°; v and v°; e, s, e° and s° and f, u, f° and u°.

$c \wedge d$ = 25° 3′	$c \wedge n^{\circ}$ = 43° 10½′	$c \wedge v$ = 70° 19′	$c \wedge f$ = 79° 45′
$c \wedge o$ = 25 3	$c \wedge r^{\circ}$ = 43 7½	$c \wedge v^{\circ}$ = 70 27	$c \wedge u$ = 79 49½
$c \wedge o^{\circ}$ = 25 4½	$c \wedge t$ = 61 46½	$c \wedge e$ = 74 54	$c \wedge f^{\circ}$ = 80 2
$c \wedge \Delta$ = 32 0	$c \wedge p$ = 61 49	$c \wedge s$ = 75 00	$c \wedge u^{\circ}$ = 79 58
$c \wedge q^{\circ}$ = 31 58	$c \wedge t^{\circ}$ = 62 00	$c \wedge e^{\circ}$ = 75 11	$c \wedge z$ = 15 6½
$c \wedge n$ = 43 2	$c \wedge p^{\circ}$ = 61 56	$c \wedge s^{\circ}$ = 75 6	$c \wedge y$ = 47 9
$c \wedge r$ = 43 3			$c \wedge x$ = 72 44

Physical properties.—Pearceite is brittle, has an irregular to conchoidal fracture and no distinct cleavage. The hardness

is about 3. The specific gravity was taken with a chemical balance on three different portions of carefully selected material and gave 6·125, 6·160 and 6·166, the mean of these being 6·15. The luster is metallic and the color of the mineral and the streak is black. The material, even in thin particles, is opaque. In the ruby silvers the arsenical compound proustite is more transparent than the antimony one pyrargyrite, and we might, therefore, naturally expect pearceite to be more transparent than polybasite, but that this is not the case may be due to the fact that the variety of pearceite under examination contains over 18 per cent of copper, while the published analyses of polybasite indicate usually about 5 and never over 10 per cent of this element.

Pyrognostics and other tests.—Before the blowpipe, pearceite decrepitates slightly and fuses at about one. Heated on charcoal in the oxidizing flame, a slight coating of As_2O_3 is formed and by addition of borax or sodium carbonate and continued heating a globule of metallic silver is obtained. In the open tube SO_2 is given off and a volatile sublimate of As_2O_3 is formed. In the closed tube the mineral fuses, yields a yellow sublimate of sulphide of arsenic and above the latter a very slight one of sulphur. The powder is readily oxidized and dissolved by nitric acid, the solution yields with hydrochloric acid an abundant precipitate of silver chloride and on addition of ammonia in excess the blue color characteristic of copper is obtained, while a slight precipitate of ferric hydroxide is formed.

Occurrence.—According to information received from Mr. Bayliss, the pearceite crystals were found with quartz and calcite lining a vug at only one place in the Drumlummon mine, and although a diligent search has been made for similar crystals in other parts of the mine none have been found. A few chalcopyrite crystals were observed intimately associated with the pearceite. High grade silver and gold ores are taken from the Drumlummon mine, and on one of the specimens of the ore argentiferous tetrahedrite, freibergite, was observed.

2. *The Crystallization of Polybasite.*

Rose originally described polybasite as rhombohedral and it was thus considered until 1867, when Des Cloizeaux* observed that the transparent plates showed in convergent polarized light a biaxial and not a uniaxial interference figure and that the mineral, therefore, could not be rhombohedral. The crystals were then referred to the orthorhombic system, but the close approximation to rhombohedral symmetry has always

* Nouvelles Recherches, p. 85, 1867.

been prominently noted in descriptions of the mineral. The earlier measurements of polybasite crystals by Breithaupt* are untrustworthy, probably owing to the difficulty of securing suitable material, and we are indebted to Miers† for the first careful series of measurements, which were made upon a suite of crystals in the British Museum. He also evidently experienced some difficulty in obtaining reliable measurements, for the angles between similar faces show a considerable variation amounting usually from a quarter to one-half of a degree. The crystals are regarded by him as orthorhombic and the following forms were observed:

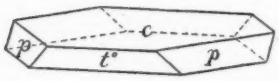
c, 001	*w*, 109	*t*, 201	*p*, 111
m, 110	*n*, 101	*r*, 112	*s*, 221

Prominent angles are $m:m$, $110 \wedge \bar{1}10 = 60° 10'$; $c \wedge n$, $001 \wedge 101 = 42° 24'$ and $c \wedge p$, $001 \wedge 111 = 61° 14'$, the axial ratio being $a:b:c = 1{\cdot}7262:1:1{\cdot}634$. He also observed that the crystals when examined in polarized light did not become dark in any position and concluded, therefore, that they were twinned, as already explained on page 20 for pearceite. He points out the impossibility of distinguishing the bevelling faces *r* and *p* in the zone between *c* and *m* from *n* and *t* in the zone between *c* and *a*, and calls attention to the fact that the only form in these zones at right angles to the base is the prism *m* and that the pinacoid *a*, 100 fails. When six faces occur in the zone of the prisms the ones which occupy the positions of the pinacoid *a* are the prismatic faces *m* in twin position.

Dana‡ accepts the measurements of Miers as fundamental but shifts the position of the crystal so that the obtuse angle of the prism, $m \wedge m$, is in front.

Among the specimens in the Brush collection at New Haven one was found from the Himmelfahrt mine, Freiberg in Saxony, showing crystals like fig. 3, which is *apparently* a combination of base and rhombohedron. On revolving the crystals in polarized light they never became dark, showing thus that

3.



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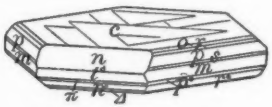


a twinning was present, while in convergent light a confused interference figure was usually obtained, although in places the

* Charakteristik des Mineral-Systems, 1832, p. 266.
† Min. Mag., viii, p. 204, 1889.
‡ System of Mineralogy, 6th edition, p. 146.

normal biaxial one was seen. There is nothing in the external aspect of the crystal to indicate twinning except perhaps the uneven character of the base *c*, which may result from a twinning about *m*, 110 and a slight deviation from 90° of $c \wedge m$. The crystal did not give satisfactory reflections, but the angle of *c* on the apparent rhombohedrons was approximately 61½° and of the latter faces on to each other 80½°. It is difficult to explain this apparently rhombohedral development on the assumption that the crystallization is orthorhombic, while it is known that monoclinic minerals whose prismatic angles are near 60°, the micas, chlorites and leadhillite for example, exhibit in a marked degree a tendency to imitate rhombohedral symmetry, while orthorhombic compounds, chalcocite, aragonite and witherite for example, do not show this tendency. It seems reasonable, therefore, to assume that the crystallization of polybasite, like that of pearceite, is *monoclinic*, and the apparently rhombohedral forms on fig. 3 have accordingly been lettered *p* and *t*° with the understanding that there is an uncertainty regarding their identification.

In the summer of 1891, while the author was engaged in some mineralogical work in Colorado for the United States Geological Survey, a collection of minerals was made at the Yankee Boy mine, near Ouray, and thanks are due to Dr. F. M. Endlich, manager of the mine, for his courtesy and the interest which he took in making the collection as complete as possible. On the specimens, associated with pyrargyrite and implanted upon quartz, were some small but remarkably perfect crystals of polybasite. The occurrence of the mineral from this locality has been noted by Endlich,* the identification being based in part upon measurements by the author of the prismatic angle $m \wedge m$ = nearly 60°.

The forms which were observed on a single crystal of polybasite, having a habit like fig. 4, are as follows, the orientation being derived from the symmetrical arrangement of the faces with reference to the prism *l*, 310, which, however, was only slightly developed and is not represented in the figure.

c, 001	Δ, $\bar{2}03$	*o*, 114	*u*, 331 ?
l, 310	*n*°, $\bar{1}01$	*r*, 112	*o*°, $\bar{1}14$
m, 110	π, $\bar{4}03$	*p*, 111	*r*°, $\bar{1}12$
n, 101	*t*°, $\bar{2}01$	*s*, 221	*p*°, $\bar{1}11$

The crystal was too opaque to admit of optical tests being made, but thinner crystals from the locality transmitted a deep red light and showed indications of twinning.

* This Journal, xl, p. 424, 1890.

The following angles were taken as fundamental:

$$c \wedge m,\ 001 \wedge 110 = 90^\circ\ 0'$$
$$m \wedge m,\ 110 \wedge \bar{1}10 = 60\ \ 2$$
$$c \wedge n,\ 001 \wedge 101 = 42\ \ 23$$

from which the axial ratio was calculated

$$a : b : c = 1{\cdot}7309 : 1 : 1{\cdot}5796$$
$$\beta = 90^\circ\ 0'$$

The following table gives a record of the measurements which were made mostly on one crystal. The ones in brackets represent approximate measurements from very narrow faces.

	Calculated.	Measured.		Limits obtained by Miers.
$c \wedge m$, 001 ∧ 110	90° 0′	90° 0′*	90° 4	
$c \wedge l$, 001 ∧ 310	90 0	90 0	90 2′	
$m \wedge m$, 110 ∧ $\bar{1}$10	60 2	60 2*	60 0	60° 10′–
$c \wedge n$, 001 ∧ 101	42 23	42 23*	42 23	40 48–42° 30′
$c \wedge d$, 001 ∧ $\bar{2}$03	31 19	31 22		
$c \wedge n^\circ$, 001 ∧ $\bar{1}$01	42 23	42 23		
$c \wedge \pi$, 001 ∧ $\bar{4}$03	50 35	50 44		
$c \wedge t^\circ$, 001 ∧ $\bar{2}$01	61 17	61 25		61 8–61 17
$c \wedge o$, 001 ∧ 114	24 31	(24 43)		
$c \wedge r$, 001 ∧ 112	42 22	(42 43)	(42 9)	40 48–42 30
$c \wedge p$, 001 ∧ 111	61 16	61 15	(61 7)	61 5–61 24
$c \wedge s$, 001 ∧ 221	74 40	(74 48)		73 55–75 50
$c \wedge u$, 001 ∧ 331	79 39	(78 2) ?		
$c \wedge o^\circ$, 001 ∧ $\bar{1}$14	24 31	(24 36)		
$c \wedge r^\circ$, 001 ∧ $\bar{1}$12	42 22	42 24		
$c \wedge p^\circ$, 001 ∧ $\bar{1}$11	61 16	(60 35)		
$l \wedge p$, 310 ∧ 111	40 35½	40 36		
$p \wedge r^\circ$, 111 ∧ $\bar{1}$12	49 26	49 27		
$r^\circ \wedge t^\circ$, $\bar{1}$12 ∧ $\bar{2}$01	49 24½	49 38		
$t^\circ \wedge l$, $\bar{2}$01 ∧ $\bar{3}\bar{1}$0	40 34	40 34		

Certainly, as shown by the above table, the agreement between the measured and calculated values is very satisfactory, and it may be assumed, therefore, that the axial ratio has been determined with a fair degree of accuracy. That the crystallization is really monoclinic is shown by the development and arrangement of the faces, but the angle β differs so little from 90° that the variation, if any, falls within the errors of observation. Of four measurements that were made of $c \wedge l$, the faces being free from striations and giving excellent reflections, two were 90° 0′ and the others 90° 2′. Six independent measurements of $c \wedge m$ were made varying between 90° 0′ and 90° 6′, but the m faces were slightly striated so that the measurements are not quite so reliable as those of $c \wedge l$.

Relations of pearceite and polybasite to each other and to other minerals.—Pearceite and polybasite show, as would be

expected, a very close relation to one another in everything which concerns their crystallization. The tendency of arsenic is to make the vertical axis of its compound a little longer than that of the antimony one, as shown by the following ratios and by the angles $c \wedge p$ or $p°$:

	a : b : c	β	$c \wedge p$ and $p°$.	
Pearceite,	1·7309 : 1 : 1·6199	89° 51′	61° 49′	61° 56′
Polybasite,	1·7309 : 1 : 1·5796	90° 0′	61 16	

Perhaps the next most interesting relation of these minerals, which imitate rhombohedral symmetry, is their very close similarity to the rhombohedral ruby silvers, proustite Ag_3AsS_3 and pyrargyrite Ag_3SbS_3, as shown by the relations of the vertical axis and the angles.

		$c \wedge p$ or $p°$			$c \wedge s$
Pearceite,	$\frac{1}{2}c = 0·8099$	61° 49′–61° 56′	Proustite,	$c = 0·8039$	61° 41½′
Polybasite,	$\frac{1}{2}c = 0·7898$	61 16 –	Pyrargyrite,	$c = 0·7891$	61 15
	Difference = ·0201			Difference = ·0148	

The vertical axes are longer in the arsenic than in the antimony compounds and to about the same extent in the two classes. In proustite and pyrargyrite s is the -2 rhombohedron, $02\bar{2}1$.

The orthorhombic sulphides, chalcocite Cu_2S and stromeyerite CuAgS, also exhibit a close and striking similarity to the minerals in question, best seen when the positions of the former are changed by a simple interchange of the a and b axes, making thus the obtuse angles of the prisms at the extremities of the b instead of the a axis, as follows:

	a : b : c	β	$m \wedge m$, $110 \wedge \bar{1}10$	$c \wedge p$ or $p°$
Chalcocite,	1·7176 : 1 : 1·6663	90° 0′	60° 25′	62° 35½′
Stromeyerite,	1·7176 : 1 : 1·6603	90 0	60 25	62 30
Pearceite,	1·7309 : 1 : 1·6199	89 51	60 2	61 49–61° 56′
Polybasite,	1·7309 : 1 : 1·5796	90 0	60 2	61 16

Although widely separated in our chemical classification, the differences in chemical composition of the two former from the two latter is not so very great, for Cu and Ag being isomorphous we have as the general composition of the former R'_2S and of the latter $R'_2S + \frac{1}{3}As_2S_3$ respectively Sb_2S_3.

On examining the whole group of sulpharsenites and sulphantimonites it is quite interesting to note that the majority of them which are well crystallized exhibit prismatic angles of nearly 60° and show forms in other zones which can be referred to vertical axes nearly like those of the chalcocite and polybasite groups. These relations are shown in the following table, where the compounds are arranged according to varia-

tions in basisity. The axes and angles have been taken from the sixth edition of Dana's Mineralogy, with the exception of those of xanthoconite and pyrostilpnite, which are taken from Miers,* and of jordanite, taken from Baumhauer.**

Name.	Composition.	Syst.	$a : b : c$	β	$m \wedge m'$	$c \wedge p$ or equivalent.	Change of axes from Dana's position.
Chalcocite	Cu_2S	O	1·718 : 1 : 1·666		60° 25′	62° 35′	$a=b$
Pearceite	$9Ag_2S . As_2S_3$	M	1·731 : 1 : 1·620	89° 51′	60 2	61 49	
Polybasite	$9Ag_2S . Sb_2S_3$	M	1·731 : 1 : 1·580	90 00	60 2	61 16	
Stephanite	$5Ag_2S . Sb_2S_3$	O	1·589 : 1 : 1·633		64 21	62 37	$a=b . \frac{3}{2}c$
Geocronite	$5PbS . Sb_2S_3$	O	1·723 : 1 : 1·732		60 16		$a=b . 2c$
Jordanite	$4PbS . As_2S_3$	M	1·862 : 1 : 1·883	90 33†	56 30	65 01	$b=c . \frac{1}{4}c$
Meneghinite	$4PbS . Sb_2S_3$	O	1·891 : 1 : 1·831		55 45		$a=b . 2\frac{2}{3}c$
Proustite	$3Ag_2S . As_2S_3$	R	1·732 : 1 : 1·608		60 0	61 41½	$2c$
Pyrargyrite	$3Ag_2S . Sb_2S_3$	R	1·732 : 1 : 1·578		60 0	61 15	$2c$
Xanthoconite	$3Ag_2S . As_2S_3$	M	1·919 : 1 : 1·523	88 47	55 4		$\frac{3}{2}c$
Pyrostilpnite	$3Ag_2S . Sb_2S_3$	M	1·946 : 1 : 1·646	90 00	53 21		$\frac{5}{3}c$
Bournonite	$3(Pb, Cu_2)S . Sb_2S_3$	O	1·875 : 1 : 1·793	$f \wedge f=$	56 8	63 48	$2a . \quad 2c$
Freieslebenite	$5(Pb, Ag_2)S . 2Sb_2S_3$	M	1·703 : 1 : 1·580	92°14†	60 48		$a=b .$
Dufrenoysite	$2PbS . As_2S_3$	O	1·531 : 1 : 1·876	$i \wedge i=$	66 18		$a=c . 2c$
Jamesonite	$2PbS . Sb_2S_3$	O	? : 1 : 1·830				$a=c . 2c$
Sartorite	$PbS . As_2S_3$	O	1·856 : 1 : 1·722		56 38		$a=b . \frac{3}{2}c$
Zinkenite	$PbS . Sb_2S_3$	O	1·794 : 1 : 1·709		58 17		$a=b . \frac{3}{2}c$

M = Monoclinic. O = orthorhombic. R = rhombohedral.

In the majority of cases in the above table the change from the position given in Dana has been made by a simple interchange of the a and b axes and by multiplying the vertical axis in its new relation by a simple factor. The isomorphous relations of jordanite and meneghinite, studied by Miers,‡ Krenner,§ Schmidt‖ and Groth¶ are not at all clear. The factor $2\frac{2}{3}$ given for the vertical axis is a rather unnatural one, which if adopted would give to the forms observed on meneghinite very complicated indices. The axial ratio suggested by Schmidt, $a : b : c = 0{\cdot}4862 : 1 : 1{\cdot}8465$, would give by interchange of a and b and using the factor $\frac{1}{2}$ for the vertical axis $a : b : c = 2{\cdot}0568 : 1 : 1{\cdot}8984$ and $m \wedge m = 51° 52′$, values which show the widest variations of any in the table from polybasite. It will be noticed that the vertical axes of the arsenical

* Min. Mag., x, p. 185, 1893.

** Sitz. Ber. Akad. d. Wiss., Berlin, 1891, p. 697.

† Owing to the change of position of the axes, the inclination for jordanite becomes γ instead of β and for freieslebenite a instead of β.

‡ Min. Mag., v, p. 325, 1884.

§ Földt. Közl., xiii, p. 297, 1883.

‖ Zeitschr. Kryst., viii, p 613, 1883.

¶ Tabellarische Uebersicht, p. 33, 1889.

compounds pearceite, jordanite, proustite, dufrenoysite and sartorite are greater than those of the corresponding antimony compounds, while xanthoconite and pyrostilpnite form an exception to this rule, which may, however, be due to inaccuracy in the measurement of the small crystals of these exceedingly rare minerals. The relations shown in the table may be accidental, but the close approximation of the axial ratios to that of chalcocite would seem to indicate that the sulphide of the metal has had a controlling influence on the crystallization. Sternbergite, $Ag_2S . Fe_2S_3$ with $m \wedge m = 60° 30'$ and enargite, $3Cu_2S . As_2S_5$ with $x \wedge x'''$, $320 \wedge 3\bar{2}0$ (twinning plane) $= 60° 17'$ might be added to the table.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, March, 1896.

ART. V.—*The Hydrology of the Mississippi;* by JAMES L. GREENLEAF, C.E.

A RIVER of the size of the Mississippi necessarily has many and important tributaries, with their individual peculiarities of watershed, channel, and variation in flow. Each of these tributaries exerts its proportionate influence upon the stream which is the resultant, and a knowledge of them is therefore essential to a study of the hydrology of the main river. For this reason, sixteen of the branches especially influential in forming the character of the Mississippi, have been selected for a brief discussion.

As a preliminary, it will be well to consider for a moment the point of view from which the engineering profession examines the hydrology of a watershed. Whatever the purpose that the engineer has in working upon a river, be it water power, water supply of towns, irrigation, the training of the current to prevent devastating overflows or to maintain a depth for navigation; in each and all of these problems two fundamental considerations force themselves upon his attention. They are the degree of regularity, and the amount of the volume of flow from the tributary country. Thus, in the south, the Mississippi River Commission and the Levee Boards find the flow volume a vital feature in their efforts to confine the stream in a definite channel. At the north, the Engineer Corps of the United States Army are constructing a system of reservoirs for holding back the freshets and aiding navigation upon the upper river during the season of low flow.

Another item of interest, if not of importance, is the amount of the annual rainfall and its distribution. Although the flow of the streams, or "run off" as it is sometimes called, depends upon the rainfall, yet it bears by no means a direct and simple relation to the latter. The percentage varies with the nature of the country, the climate, and the season of heaviest rainfall, from eighty or ninety down to less than five per cent. Merely

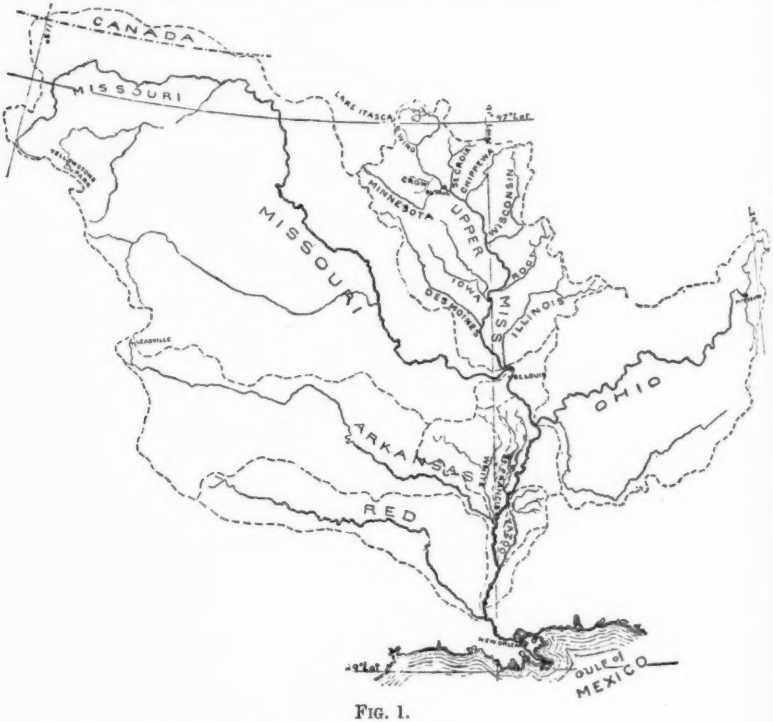


FIG. 1.

to suggest some of the causes of its variation, the following may be mentioned. A steep and rocky region will rapidly pour most of its rainfall into the stream. A level country, over which the water settles and flows off slowly, may expend nearly all in evaporation. A sandy soil absorbs the rain like a sponge as fast as it falls, to feed the never failing springs, and consequently gives a high ratio of flow; or, on the contrary, the water may sink too deep for that, and possibly make its first appearance in some far distant valley belonging to another watershed. A winter rain storm will perhaps all find its way

over the frozen ground to the water channels, and a summer shower may be entirely absorbed by the thirsty land and growing vegetation. In fact, the ratio of "run off" to rainfall is so uncertain, that engineers consider volumes of flow deduced merely from records of rainfall of small importance, as compared with a long series of actual gaugings of the stream. But gaugings are seldom available, and hence the percentage that the flow bears to the rainfall is of more than mere scientific interest.

From the foregoing it may be concluded that, in studying the hydrology of a watershed, the engineer considers the area of drainage, the rainfall and its distribution through the seasons, the temperature, the character of the region as influencing the percentage and regularity of flow, and, most valuable of all, actual gaugings of the streams—if he can obtain them.

The basis of this discussion of the Mississippi is a report by the writer upon certain water-powers for the Tenth Census of the United States. The data there given have been amplified to cover the flood and low water as well as the average discharge of the Mississippi and its tributaries, and have been brought up to date by study of the subsequent gaugings conducted by the Corps of Engineers of the United States Army. Acknowledgment is due to this source of information, without which any study of the river would be impossible, and also to the many individual members of the Corps from whom courteous replies have been received to letters of inquiry concerning details. It is believed that the conclusions here offered are an essentially correct statement of the conditions of flow pertaining to the Mississippi watershed. The yearly reports of the United States Corps of Engineers, which are awaited with interest, will either substantiate still further the diagrams here offered, or furnish data for their alteration.

Figure 2 illustrates some of the principal features of the branches selected as especially influencing the Mississippi. The shaded rectangles represent the watersheds in the order of their occurrence from the source to the mouth, and the unshaded rectangles the intermediate areas tributary directly to the main river. The horizontal widths of the rectangles are proportional to the respective drainage areas, and their heights show the yearly average flow in terms of cubic feet per square mile per second. The areas of the rectangles may therefore be said to give a measure of the relative influence of the tributaries upon the average discharge of the main stream.

The diagram exhibits the peculiarities of the tributaries, but fails to furnish an explanation, and that information we must seek for. It will be noticed on the diagram, that the rainfalls, shown by the horizontal lines, increase from the north toward

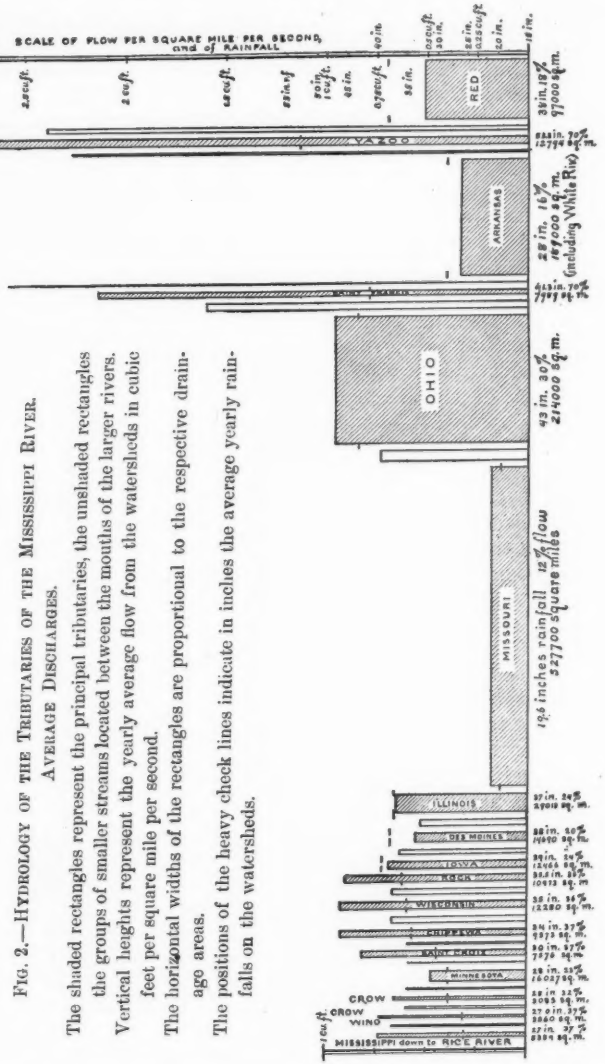


FIG. 2.—HYDROLOGY OF THE TRIBUTARIES OF THE MISSISSIPPI RIVER.

AVERAGE DISCHARGES.

The shaded rectangles represent the principal tributaries, the unshaded rectangles the groups of smaller streams located between the mouths of the larger rivers.

Vertical heights represent the yearly average flow from the watersheds in cubic feet per square mile per second.

The horizontal widths of the rectangles are proportional to the respective drainage areas.

The positions of the heavy check lines indicate in inches the average yearly rainfalls on the watersheds.

the south, attaining one maximum on the Iowa basin. Also, the main stream down to Rice River, the Crow Wing, Saint Croix, Chippewa, Wisconsin, and Rock, may be termed high flow streams. Their percentages of flow to rainfall are from thirty-

five to thirty-seven, and in this respect they are only equalled by some of the tributaries in the far south. The actual volume of flow, however, is not as great as the figures might lead one to infer, for the annual rainfall is slight, being over a portion of the tributary region only twenty-seven inches in depth. In consequence these streams yield a yearly flow of 0·625 cubic feet per square mile per second, rising to 0·928 cubic feet in the case of the Wisconsin, while the Ohio, for example, although only a thirty per cent stream, gives 0·953 cubic feet of average flow, because of its greater rainfall.

Why is it that the percentage of flow to rainfall for the rivers mentioned, is sufficiently large to raise them into the list of high flow streams in spite of their light rainfall? It may be due, in part, to the spring rainfall being slightly greater relatively to the summer rainfall for the first five hundred miles or so of the Mississippi than for the second, and to the later advance of warm weather at the upper waters causing a delay in evaporation, and in the demands of vegetation. But the principal reason must be sought in the character of the country drained. A sandy soil that absorbs the rain and yields it to the streams with comparatively little loss from evaporation is a feature of a large part of this region. Pine forests that check the dry winds and moisture-searching sun of summer also abound at the sources of the Mississippi, Saint Croix, Chippewa, and Wisconsin.

In contrast to the high flow tributaries is the Minnesota. This river has nearly the drainage area of the Mississippi above where the Minnesota enters it, but in the volume of flow does not approach to the importance of the latter. It is a true "prairie stream," running high at one season, and then dwindling with dry weather, or a cold winter, to almost nothing. Its percentage of average flow to rainfall is only twenty-three, and its average discharge is 0·474 cubic feet per square mile per second. The Iowa and Des Moines likewise flow from an open prairie country and are no better in ratios of flow, yielding only twenty-four and twenty per cent respectively, but in them the increased rainfall shows its effect. Upon these watersheds there is a rainfall of thirty-eight inches annually as against twenty-eight for the Minnesota, and the ten extra inches raise the rectangles considerably above that for the latter river.

The Illinois drains 29,000 square miles to the east of the Mississippi, and is the most important tributary met with thus far in passing down the river. Its rainfall, percentage of flow, and discharge per square mile happen to be almost precisely the same as for the Iowa. The drainage basin also is similar in many respects. The land is level, or gently undulating, but not quite so pronounced a prairie region as the country lying

west of the Mississippi. An extensive swamp drains into its head waters from Indiana.

Just below the Illinois is the mouth of the Missouri. Its drainage area is three times as great as that of the entire Mississippi above the junction. It rises in the heart of the Rocky Mountains and flows for nearly three thousand miles through mountain land and prairie. Greatly varying conditions of hydrology prevail within the limits of the watershed, but one fact stands pre-eminent: of all the branches of the Mississippi it makes the poorest record for the area it drains. If its flow was proportionately as great as from the Ohio, its discharge alone would equal the entire volume that passes New Orleans each year. The diagram illustrates the peculiar weakness of the Missouri, due primarily to its low average rainfall, and to the extremely small percentage of flow. Twelve per cent of less than twenty inches rainfall give only 0·178 cubic feet per square mile per second for the average discharge. It is well to remember, however, that these are averages, and that in flood the Missouri is a mighty torrent of muddy water.

A short distance below the mouth of the Missouri, the Ohio enters, with less than half the drainage area of the former, and more than the total yearly discharge. It reaches so far eastward that dwellers on the Atlantic coast look upon its upper waters as neighboring streams. Mountains and woodland cover a large portion of its basin. The rich, undulating farm lands of Ohio, Indiana and Illinois are tributary to it. The large average discharge is not due especially to the percentage of flow, for its thirty per cent is a moderate amount, but to the forty-three inches of annual rainfall. The warm moist air currents which flow from the Gulf region up the Mississippi valley have a decided tendency to the north and east rather than westerly, and this is chiefly the cause of the preponderance of the Ohio over the Missouri. The area of its rectangle in the diagram equals seven-ninths of the combined areas of all the rectangles preceding it, including the Missouri.

The Arkansas is another large river entering from the west, draining 189,000 square miles, and is in many respects a small imitation of the Missouri. Its average ratio of flow to rainfall is only sixteen per cent, and all that tends to raise its standing is the larger average rainfall of twenty-eight inches.*

The Red River is the last important tributary of the Missis-

* The White River, draining 28,000 square miles, has been included with the Arkansas in Figure 2. It is true that they enter the Mississippi together, but strictly speaking they are distinct rivers. It will be noticed that where it is more necessary, as in Figure 4, the Arkansas and White are given separate treatment.

sippi. It flows from the west, bringing the drainage of 97,000 square miles. It maintains not only a slightly better ratio of flow than the Arkansas, but is subject to a decidedly higher rainfall. The former is eighteen per cent, and the latter averages over thirty-eight inches annually. As a result, the Red River yields an average discharge of 0·515 cubic feet per square mile per second. The mouth of the Mississippi is, in a hydrological sense, situated where the Red River enters it, for at this point the Atchafalaya Bayou taps the river and draws off a considerable share of its waters.

It will be noticed that two rivers of marked peculiarities are represented in the diagram. The Saint Francis and the Yazoo are the largest of several streams entering in the vicinity of the Arkansas and the Red, which are comparatively small and do not extend far to the west or east. They are consequently directly in the track of the heavy raineloud from the Gulf. The rainfall upon their watersheds either sinks rapidly into the sandy soil and thus escapes evaporation, as is the case on a large part of the Yazoo watershed, or else flows quickly into the swamp reservoirs that characterize both the Yazoo and the Saint Francis. Hence the ratio of flow is as high as seventy per cent of the rainfall, and the yearly average flow amounts to 2·130 cubic feet per square mile per second, for the Saint Francis, and to 2·749 cubic feet for the Yazoo.

The second diagram, giving the average flow and rainfall lines of the Mississippi River, follows directly from the diagram of the tributaries. Its special interest lies in the information it affords as to the resultant effect which the branches have upon the main river. The line of flow, "CCC," gives in cubic feet per second the yearly average of total flow at each point from source to mouth. This line will be seen to corroborate a previous statement concerning the large discharge of the Ohio River.

The line "BBB" gives in inches, at any point selected, the yearly precipitation in rain and melted snow, averaged for the entire area tributary to the Mississippi above the point in question. If the point selected is at the mouth of some inflowing river, the line shows the average rainfall above its tributary watershed, and also the effect of including this watershed in the general average.

The line "AAA" is by far the most significant of the three in the study of the hydrology of the Mississippi. It represents for each point from source to mouth the yearly mean flow in cubic feet per square mile per second, averaged for the entire area tributary to the Mississippi above the point in question. If the point selected is at the mouth of some inflowing river,

the line shows the average flow from the area above its tributary watershed, and also the effect of including this watershed

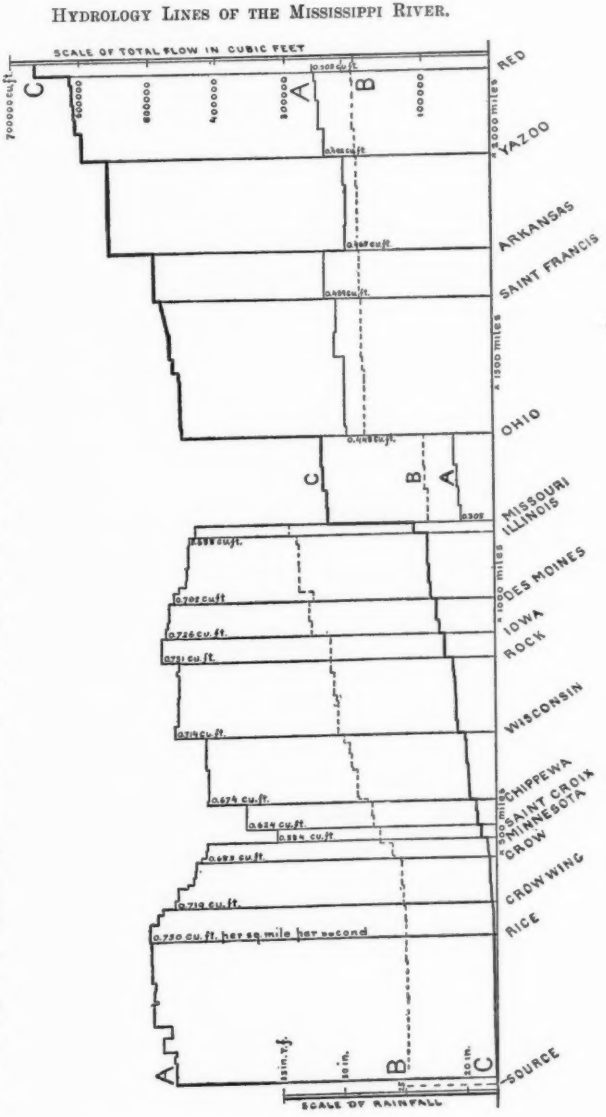


Fig. 3.—The line AAA represents, for any point from source to mouth, the yearly mean flow in cubic feet per square mile per second, averaged for the entire area tributary to the Mississippi above the point in question.
The line BBB gives in inches, at any point selected, the early rainfall averaged for the entire area tributary to the Mississippi above the point in question.
The line CCC gives in cubic feet per second the yearly average of total flow at each point from source to mouth.

in the general average. The line "AAA" is not a simple exponent of totals, as is the line "CCC" of total flow. It is a function of the varying average of rainfall, the varying tributary area as the branch streams are passed, each with its large or small watershed, and the varying percentage of flow to rainfall in force upon these side basins. In the use of this line area enters as a factor of equal importance with volume in the study of the hydrology of the river.

It will be noticed that the effect of any one tributary area upon the line "AAA" is much less marked toward the mouth of the Mississippi than would be the case if its watershed were located at the upper waters. The obvious reason is that it has the weight of all the large areas tributary above it to work against before it can influence the general average. If, for example, the Yazoo and Wisconsin, which have nearly equal drainage areas, were to change places, the latter would cause but slight alteration in the lower end of the line, while the Yazoo, in its new position, would raise the line to a flow of over one cubic foot per second.

It remains to see what general deductions the diagram affords. In the first place, it shows that there is abundant reason for the popular division of the river into the upper and lower Mississippi. The line "CCC" gives the upper river a gradual increase of volume to where it joins the Missouri. At that point begins the lower Mississippi, and the great accretions from the Missouri, and especially the Ohio River, immediately force the line to a higher level. Then the Arkansas and Red Rivers make the rate of increase much greater than for the upper Mississippi. But the line "AAA" exhibits in a decided manner a difference still more fundamental between the upper and the lower divisions of the river. A glance along this line from source to mouth will make apparent the great depression that it undergoes from the Missouri south. The upper river is a high flow stream throughout its length. The lower river belongs just as decidedly with the low flow class.

The depressing effect that the prairie streams have on the Mississippi is marked. Wherever a drop occurs in line "AAA" it is caused by a river upon which prairie influences prevail. The Crow Wing, Crow, Minnesota, Iowa, Des Moines and Illinois exert such effect. The Arkansas causes a decided drop in spite of the large area above that its watershed is averaged with. The Red River alone, of all its class, does not lower the line. This is due in part to its large rainfall, and partly to the line being already well pulled down by the Arkansas to meet it. As for the effect of the Missouri, it is deserving of special notice. A profound drop in line "AAA" occurs at its mouth. If it were not for this, the main river would continue a high

flow stream to the Gulf. The extremely small rainfall and percentage of flow of the Missouri, coupled with its half million square miles of drainage area, determine the main river to its mouth. The pronounced high flow character of the Ohio results in the lifting of the line "AAA" at once through forty per cent of the drop occasioned by the Missouri, but even the Ohio, magnificent as it is in drainage area, and with a high rank among the tributaries for its volume of flow, cannot redeem the character of the Mississippi after its debasing union with the Missouri River.

It is interesting to notice that the dual action of the Missouri and Ohio has its imitation toward the north. The low flow Minnesota causes, on a small scale, a drop in the line "AAA" similar to that produced by the Missouri, and below it the Saint Croix and Chippewa are the first of a series of branches culminating in the Rock River, which more than make good the depression.

The influence of the heavy rainfall and large percentage of flow in the south is shown by the gradual rising of the line "AAA." The Saint Francis and Yazoo and lesser streams, draining all together only 43,000 square miles, make a perceptible headway in the averages, even against the inertia of all the vast drainage area lying to the north, east and west of them. If their condition of rainfall and flow prevailed over the entire 1,259,000 square miles forming the Mississippi watershed, the average discharge would be fully three million cubic feet per second; more than forty times its actual volume. These figures indicate what the Mississippi, grand river that it is, might be if the trade winds and moist air currents from the Gulf of Mexico did but sweep the semi-arid regions to the northwest, and pour a plenteous rainfall over their vast extent.

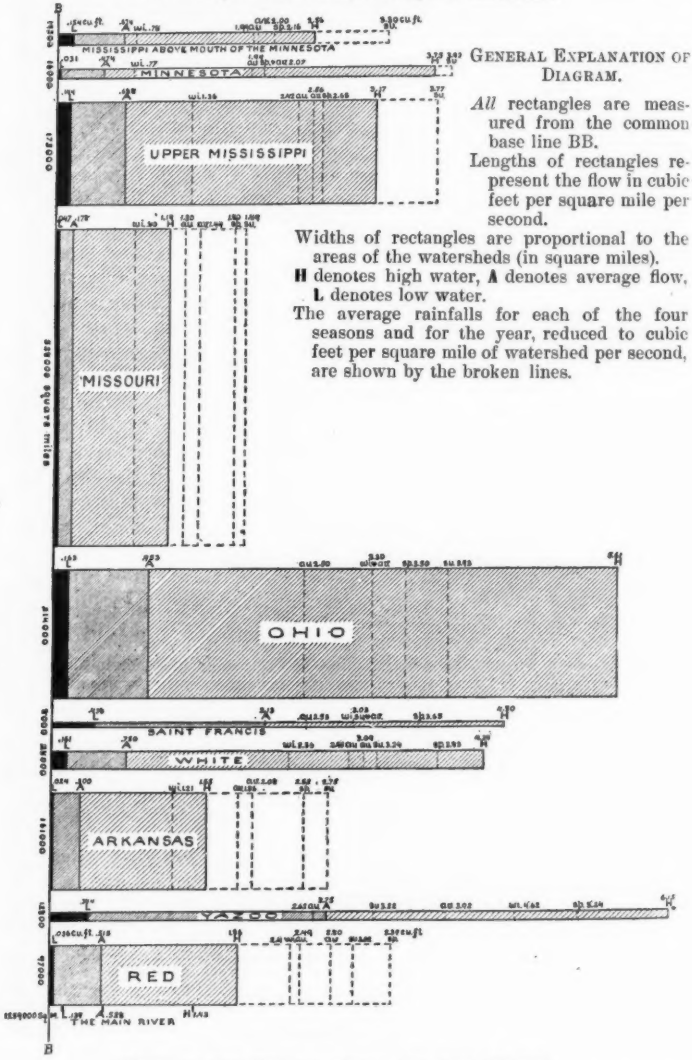
Thus far the discussion has been confined to a study of average flow, and is therefore open to the criticism that all averages are liable to, for it states nothing concerning the variations of flow characteristic of the rivers. Indeed, the average flow may even be looked upon as a theoretical quantity, inasmuch as it has no real and tangible existence, except for a few brief periods during the year. No apology need be offered for its presentation, however, for a study of averages is an important aid to the understanding of the actual relation of flow which the rivers bear to one another. Attention will now be given to the variations in the volume of flow of the tributaries of the Mississippi, and the relations which these variations bear to the climatic and topographical features of the watersheds. Figure 4 and the subsequent notes present particulars concerning rain-

fall, minimum and maximum flows, and the time variations in the amount of flow for each of the principal tributaries.*

A glance over the diagram makes wide differences apparent. The Ohio, Yazoo, Saint Francis and White have comparatively large flood flows per square mile per second. The Arkansas, Red, Missouri and Minnesota have especially small flows per square mile per second. The determinating causes for these and other differences are the amounts of rainfall on the watersheds, the distribution of these amounts through the seasons, the degree of storage of winter precipitation to be liberated in the melting of the snow and ice at spring time, the nature of the country and vegetation, and the amount of natural storage in the form of lakes and swamps. It should be borne in mind that the southern rivers of limited drainage area have a heavy rainfall, and a large amount of this occurs in the winter and spring, when evaporation and the demands of vegetation are slight. The same is true of the Ohio watershed, because of the marked tendency for the moisture laden air-currents to flow over it to the northeast in the early months of the year. For these reasons one would expect the southern rivers to carry high rates of flood-volume as compared with streams differently conditioned. The tributaries farther north, on the contrary, and particularly the Arkansas and Missouri, which extend their lines of drainage far westward, have average amounts of annual rainfall greatly below that of the Ohio, for example, and of this the greatest activity occurs in summer, when the tendencies are strongest to absorb and evaporate it

* Adverse criticism is almost inevitable when one puts in concrete form conclusions from a series of data which are so liable to various interpretations as are gaugings of the flow of rivers. It is very largely a matter of judgment as to what shall be taken for the characteristic minimum flow or maximum flow, and one's impression of the time of occurrence of the annual greatest flood, or of low water, is apt to be influenced by some special case which has fixed itself on the mind, rather than by impartial averages. It is the latter that I have tried to follow. I hope to disarm adverse criticism by frankly holding myself open to conviction regarding the conclusions offered, and by stating that they are the result of a somewhat extensive study of all the available gaugings by the United States Engineer Corps, checked and compared with the opinions so kindly given by a number of the officers stationed along the rivers. The aim has been to give the discharges at decidedly low and high water, but at the same time to avoid using any special and extreme case as a criterion. It is proper to state that discharge data concerning the Yazoo and, above all, the Saint Francis, are especially meagre and more or less uncertain. Capt. Willard's gaugings upon the Yazoo are about the only reliable figures to start with. The Saint Francis is so liable to overflow from the main river as to make gaugings of it well nigh impossible of interpretation. Fortunately the climatic conditions are quite uniform over the region of country concerned, giving some authority to a comparison between neighboring watersheds of limited extent. Therefore, by comparing first the Yazoo and White, giving due value to the proportions of upland and bottom land, and then applying the results to the Saint Francis, and checking by a proper balance between the three rivers, results have been obtained which I believe to fairly represent the truth.

FIG. 4.—HYDROLOGY OF THE TRIBUTARIES OF THE MISSISSIPPI RIVER, HIGH, AVERAGE, AND LOW DISCHARGES, AND RAINFALL.



GENERAL EXPLANATION OF DIAGRAM.

All rectangles are measured from the common base line BB.

Lengths of rectangles represent the flow in cubic feet per square mile per second.

Widths of rectangles are proportional to the areas of the watersheds (in square miles).

H denotes high water, **A** denotes average flow, **L** denotes low water.

The average rainfalls for each of the four seasons and for the year, reduced to cubic feet per square mile of watershed per second, are shown by the broken lines.

NOTES ON THE TIMES OF HIGH AND LOW WATER.

Mississippi above the Minnesota. *High.*—Rise begins in early April, due to Spring rains and melting snow—reaches a max. in end of April to May, and often is the max. of the year. Effect of melting ceases, but rains maintain a fair stage. Decided rise in June to July, due to rains—sometimes the highest of the year. Generally a brief Fall freshet.

Low.—The low water of Fall occurs in August to Nov.—usually lowest in end of Sept. to mid. Oct. Lowest water of year in end of Nov. to end of Dec., due largely to freezing of the ground.

Minnesota.—Practically the same in period of rise and fall as the Mississippi above it, but much more fluctuating in amount, because of the comparatively few lakes and swamps, and more open prairie on its watershed.

Upper Mississippi (down to Missouri River). *High.*—Rise begins in Feb., due to rains and melting snow. A good stage maintained well into July. Usually two occasions of especially high water. The smaller may occur any time from latter part of Feb. to end of March, due to rains and melting snow. The greater may occur any time from April to July, due to rains and somewhat to melting snow. There is often a brief Fall freshet.

Low.—The lowest water of the Fall occurs in Aug. to Oct., generally in Oct. The lowest of the year is in Dec, due largely to freezing of the ground.

Missouri. *High.*—The volume of flow increases from early in Feb. on, reaching a max. in April, due to rains and melting snow. Owing to the large differences of elevation on the watershed, melting snow influences the stage of the river until Aug. A fall occurs in May, as the bulk of the snow disappears. Then there is a rise in June to the max. for the year, falling in July and Aug.

Low.—The river runs low in Sept., Oct. and Nov., and in the latter part of Nov. into Dec. occurs a sudden drop to the lowest stage of the year, due to freezing of the ground.

Ohio. *High.*—The river usually begins to rise in the latter part of January and is liable to maintain a fair stage until into July. In latter part of Feb. on, into the latter part of March, occurs the max. rise of the year, due to winter and spring rains and melting snow. Again, in April to middle of May is the height of a secondary rise, due to rains solely. The Fall rains cause an occasional rise in Nov.

Low.—The low water is in August through to Jan., and the lowest is any time from the first of Oct. to the middle of Nov.

Saint Francis. *High.*—The river rises to a good stage in the middle to end of Jan., diminishing through May. The highest stage usually occurs in the latter part of March.

Low.—Low water runs through Sept. to Dec., usually reaching the lowest point in the end of Oct. to the end of Nov.

White. *High.*—There is usually a good stage from Jan. to June, a fall sometimes intervening. The highest water may occur any time between those limits, with the chances in favor of its coming in May.

Low.—Low water occurs from July into Dec., and the lowest stage of the year from Sept. to Nov., especially in Nov.

Arkansas. *High.*—A good stage of water is liable from Jan. to June. A max. occurs in Feb., and again in April or May, and the chances are about even in the long run for either of these being the max. for the year. There is often a brief freshet in the Fall.

Low.—The river falls in July, and, except for Fall freshet, runs low into Dec. Lowest stage of the year is liable from end of Sept. to middle of Nov.

Yazoo. *High.*—There is a good stage of water from Jan. to June or July, culminating usually in April. An irregular and occasional rise occurs any time from Aug. to Dec.

Low.—The river runs low as a rule from July through Dec., reaching a minimum in the latter part of Oct. to the end of Nov.

Red. *High.*—The river rises in Jan. and holds a fair stage until into June. The highest water of the year may occur any time from Feb. to May, and probably in April to May. There is an occasional short rise in late Summer or Fall.

Low.—The river falls in July and runs low as a rule until in Dec. The lowest water for the year may occur in Sept, Oct. or Nov.

The Main River. *High.*—The river begins to rise early in January, and attains a max. stage usually in latter part of April or May, falling in June, July and August.

Low.—The low water occurs from Sept. on to the end of the year, reaching the lowest point, as a rule, in Nov.

Table of Rainfall and Discharge Data for the Principal Watersheds of the Mississippi System.

Watershed.	Rainfall.										Flow per Second.					
	Annual.		Spring.		Summer.		Autumn.		Winter.		Minimum.		Average.		Maximum.	
	Inches. Depth.	Cu. ft. per sec. per sq. mile.	Inches. Depth.	Cu. ft. per sec. per sq. mile.	Inches. Depth.	Cu. ft. per sec. per sq. mile.	Inches. Depth.	Cu. ft. per sec. per sq. mile.	Inches. Depth.	Cu. ft. per sec. per sq. mile.	Total in 1000's of cu. ft.	Cu. ft. per sec. per sq. mile.	Total in 1000's of cu. ft.	Cu. ft. per sec. per sq. mile.	Total in 1000's of cu. ft.	Cu. ft. per sec. per sq. mile.
Mississippi above mouth of Minnesota Riv. (19,500 sq. miles)	27·2	2·000	7·1	2·158	10·7	3·296	6·8	1·994	2·7	0·780	3	0·154	13	0·674	50	2·56
Minnesota (16,000 sq. miles)	28·0	2·061	7·0	2·070	11·8	3·476	6·6	1·944	2·6	0·772	0·5	0·031	7·6	0·474	[1]60	3·75
Upper Mississippi above mouth of Missouri Riv. (173,000 sq. miles)	34·7	2·555	9·0	2·650	12·8	3·769	8·2	2·415	4·6	1·355	25	0·144	118	0·688	550	3·17
Missouri (528,000 sq. miles)	19·6	1·443	6·1	1·796	6·4	1·885	4·4	1·296	2·7	0·795	25	0·047	94	0·178	600	1·14
Ohio (214,000 sq. miles)	43·1	3·173	11·9	3·504	11·8	3·925	8·5	2·503	10·9	3·210	35	0·163	204	0·953	1200	5·61
St. Francis (80.000 sq. miles)	41·3	3·041	12 4	3·652	10·2	3·004	8·6	2·533	10·3	3·033	[2]3·5	0·438	17	2·130	[4]36	4·50
White (28,000 sq. miles)	42·0	3·092	13·0	3·828	11·0	3·239	10·0	2·945	8·0	2·356	4·5	0·161	20	0·750	120	4·29
Arkansas (161,000 sq. miles)	28·3	2·082	8·6	2·518	9·3	2·748	6·3	1·864	4·1	1·207	4	0·024	48	0·300	250	1·55
Yazoo (13,000 sq. miles)	53·3	3·924	17·8	5·239	10·9	3·222	8·9	2·621	15·7	4·615	[3]5	0·384	35	2·749	[4]80	6·15
Red (97,000 sq. miles)	38·3	2·798	11·5	3·386	10·2	3·019	8·4	2·485	8·2	2·400	3·5	0·036	50	0·515	180	1·86
Mississippi above its mouth (1,259,000 sq. miles)											175	0·139	664	0·528	1800	1·43

[1] Probably much exceeded at times.

[2] Obtained from a comparison of the Yazoo and White.

[3] Derived chiefly from gaugings by Captain Willard; checked by comparison with the White.

[4] Result chiefly of a comparison with the White, allowing for differences of rainfall and topography.—Somewhat uncertain.

before it reaches the streams. Again, heavy rainfalls are liable to be somewhat local in their extent, when the entire drainage basin of a large river is considered. In the case of the Missouri, for instance, while the early spring rains are falling upon the regions near its mouth, the upper and elevated watershed is supplying comparatively nothing to the flow. The natural tendency of such a condition as this is to pull down the average rate of the high flow per square mile for an extensive drainage area. On account of the above reasons it is not surprising that the northern and large western tributaries of the Mississippi should carry comparatively small rates of maximum flood volume per square mile. To be sure, they have an advantage over the strictly southern rivers in drawing upon large quantities of melting ice and snow which may concentrate the winter precipitation in a brief period of melting. The winter precipitation upon their basins, however, is far lower in rate than for the other three seasons of the year, and the melting occurs chiefly before the heaviest rainfalls, which tend toward the late spring or summer. There result from this simply two freshets, the first due to melting aided by rains, and the second due principally, if not entirely, to rains alone. Between these two freshets occurs a more or less pronounced tendency to a merely fair or average stage of water.

Upon turning to consider the rates of low flow and their causes one is confronted at once with the much smaller annual rainfall upon the entire northern and western portion of the Mississippi watershed. Behind this prominent fact are a number of minor considerations. Thus, the proportionate, and probably the absolute loss from evaporation and absorption by vegetation is greater for regions with a light, than for those with a large rainfall. The proportion of natural storage per square mile in the form of lakes and swamps is smaller for large than for small watersheds. Finally, the climatic conditions are such over the major part of the Mississippi watershed, that the period of light rainfall in the autumn dominates a wide extent of country. So, while it is true that all portions of any one of the large watersheds will not at any one time be giving their maximum flood volume for the year, the converse is not true, for they may uniformly concur in yielding their minimum flows. The entire watershed of the longest tributary of the Mississippi, for instance, may at one and the same time be suffering from a greatly diminished rainfall, and one part of the area cannot be counted upon to maintain the flow while another part is subject to drouth. The above causes readily account for the exceedingly low flow per square mile of 0·047 cubic feet per second from the Missouri, and 0·024 cubic feet from the Arkansas, and for the uniformly low rate of minimum

flow from all the smaller streams in the northwestern part of the Mississippi watershed.

Passing now to the extreme upper waters of the river, the upper Mississippi above the mouth of the Minnesota, and the Minnesota itself show certain interesting and instructive differences. The total amount and the distribution of the rainfall is nearly the same for both, the Minnesota having a slightly more pronounced concentration of rainfall in the summer months. The Minnesota is preëminently a prairie stream, whereas the main river is characterized, to an unusual degree, by lakes and swamps. It is not strange, therefore, that the flood-flow per square mile is nearly fifty per cent larger from the Minnesota than from the main stream. Neither is it to be wondered at that the Minnesota dwindles away to 0·031 cubic feet per square mile per second in low water, exhibiting the true character of a prairie stream, while the natural lakes and swamps of the main river hold it, in spite of the low rainfall, up to 0·154 cubic feet per square mile per second.

The upper Mississippi, at the point where it unites with the Missouri to form the lower river, takes high rank in the matter of rates of flow, in spite of its average climatic conditions being essentially those already described as pertaining to the northern and western tributaries. Its high rate of low flow is largely the result of the natural storage in the immense number of lakes and swamps in the States of Minnesota and Wisconsin. This storage affects to a marked degree the main river above St. Paul, the Saint Croix, Chippewa, Wisconsin, and other tributary streams. As a result, these rivers withstand very successfully the depressing effect of the prairie streams like the Minnesota, which enter from the west, and they maintain the low flow at 0·144 cubic feet per second per square mile.* But not alone in its low flow as compared with the climatic conditions, is the upper Mississippi noticeable. Although its average annual rainfall is slight, yet it has heavy summer rains widely enough distributed over its 173,000 square miles of watershed to hold it well up toward the ranks of the high flood-flow tributaries. Also, its spring melting is sufficiently concentrated in point of time to have a very important influence upon the records of flood volume.

The Ohio demands special mention because of pronounced activity among its fellow tributaries. In a hydrological sense

* Attention is here called to the fact that this paper is written throughout with reference to the natural conditions of the Mississippi drainage; the conditions which would pertain if the artificial storage works installed by the United States Government at the sources of the river were not existing. These works, uncompleted as they are, have resulted in maintaining a stage at St. Paul during the low season considerably more than a foot above the natural conditions of the river.

it is the ruling tributary of the Mississippi system. Although it has less than half as large a drainage area as the Missouri, yet its low, high, and average flows all exceed in total amounts the like volumes from the Missouri. In rates per square mile, these flows are only exceeded in the cases of certain southern rivers. In fact, the Ohio is rightly classed with the southern rivers, even granting that the annual melting of snow and ice is a prominent feature upon its basin. It has been pointed out that upon most extended drainage areas, the rate of high flow is pulled down by the averaging of districts where the rains may be falling, with regions that happen at that time to be comparatively dry. Not so for the Ohio. There is a strong tendency for moisture-laden air to be whirled in broad sheets over the watershed clear to the Alleghanies, and deposit heavy rainfalls during the same month over nearly the entire length of the basin. When this is taken into account with the relatively large average rainfall of 43 inches, and with the fact that the winter rains are only slightly less in amount than those of spring, the greatest of the year, and occur at the time when the snow and ice are going out, it is easy to understand why the Ohio should tower far above the other large tributaries of the Mississippi in its rate of high flow. That the Ohio is above even the upper Mississippi in its rate of low flow, is due primarily to its higher annual rainfall, and also to its important southern branches extending into a region of considerable autumn rainfall.

The lower Mississippi, the main channel into which all the tributaries flow, claims final attention. It is the resultant of these tributaries, but a resultant in which the element of time is a potent factor. If all the tributaries were high and low together, it would be easy to compute the high flow or low flow of the main stream by a simple process of summation. Owing, however, to a lack of unanimity among the streams in this respect, it is an exceedingly complicated and, in fact, impossible task to reason out conclusions concerning the flow of the main river simply from the general data for the tributaries. The tributaries do conspire to a considerable degree in producing the low stages of the main river, for the area of light rains in the fall is very widely extended over the Mississippi watershed. All the rivers are not at their lowest during the same time, however, for if they were the aggregate flow would be only 110,000 cubic feet per second, whereas the low water discharge of the Mississippi may be taken at 175,000 cubic feet per second, although lower gaugings have been recorded.

Fortunately for the well-being of the dwellers within the Mississippi valley, the tributary streams differ very widely in their times of flood. A simple calculation shows that if high

water occurred simultaneously with them all, the main river would have to carry over three millions cubic feet of water per second to the Gulf. As a matter of fact, it is an extremely rare coincidence for more than two of the large tributaries to be at their highest yearly stages at the same time. The greatest annual flood upon the Ohio, for example, has disappeared before that from the Missouri reaches the Mississippi. Thus the aggregate in the main river is kept down, so that 1,800,000 cubic feet per second may be considered a large flood discharge from the Mississippi. The combination of conditions is such that the lower river usually reaches its maximum volume for the year in April or May, and its lowest stage in October or November. The diagram shows, by a convenient comparison of rates of flow per square mile per second, the resultant effect of all the tributaries upon the main river. The rate of low flow, 0·139 cubic feet per square mile per second, is fairly well up, in spite of the downward pull given by the Missouri and Arkansas. The rate of high flow is kept down to 1·43 cubic feet per square mile per second,—which is only surpassed in smallness in the case of the Missouri,—by the above mentioned lack of coincidence in the times of flood from the various tributaries.

ART. VI.—*Preliminary Note on the Relations of Certain Body-plates in the Dinichthyids;* by C. R. EASTMAN.

THANKS to the energy and skill of the local Ohio collectors in bringing together and developing fresh material, and to the painstaking descriptions of Newberry, Claypole, Wright and others, palæontologists have gradually become familiar with the principal features of Dinichthyid anatomy. Few chapters in the history of American palæontology are more interesting or instructive than that relating to the discovery and systematic fitting together of the detached parts, as rapidly as each new piece was brought to light, until finally almost the entire skeleton of these huge *Arthrodira* has been accurately reconstructed. For skill in determining isolated fragments and assigning them to their natural position, and for sagacity in tracing out the homologies with European Coccosteans, the work of these authors leaves nothing to be desired; and so thoroughly has every scrap of material been overhauled and scrutinized in the search for new evidence, that the structural details which still remain to be completed are relatively insignificant.

The object of the present paper is to communicate a slight

amount of additional evidence regarding the body-covering of the Dinichthyids. It is intended first to give a brief description of two plates which complete the median ventral armor of *Titanichthys;* second, to locate a plate of *Dinichthys* which has been known for a long time in a more or less imperfect condition, but whose exact relationships have never been definitely determined; and third, to call attention to the peculiar "nail-head" termination of the median dorsal shield in *Dinichthys.* The illustration of the parts presently to be described, together with more detailed observations on the structure of the Dinichyids, is deferred until another time.

The material upon which the following notes are based was brought together by that indefatigable collector, Mr. Jay Terrell, of Oberlin, Ohio. It is all from the Cleveland Shale of Lorain County, Ohio, and is now preserved in the Museum of Comparative Zoology at Cambridge, Massachusetts.

Median ventral plates of Titanichthys.—Three perfectly preserved specimens afford a complete insight into the structure of the median portion of the plastron in *Titanichthys,* and we may assume that essentially similar elements were present in *Dinichthys.* Heretofore only one element has been provisionally assigned to the ventral surface of *Titanichthys.* Newberry mentions such an one, but was disposed to regard it as the equivalent in itself of the five distinct plates which constitute the plastron of *Coccosteus.** There can be no doubt as to the identity between this plate and the one figured by Claypole in Volume VII. of the Palæontology of Ohio,† which is also provisionally referred to *Titanichthys.* The third specimen is that examined by the writer; and it confirms Claypole's determination of the genus, and also his identification of it as a median ventral. This specimen is more perfect in outline than Professor Claypole's, and shows distinctly a wide impressed area on the four sides of the lozenge, formed by the overlapping margins of the anterior and posterior pair of ventrals, thus proving that the plastron of *Titanichthys* was constructed on the same general plan as in *Dinichthys* and *Coccosteus.*

There are two unique specimens in the Terrell Collection representing the anterior median ventral. The larger plate is 28^{cm} long, and 18^{cm} wide at the base. It is perfectly symmetrical; and, as seen from the dorsal side, lanceolate in outline, and traversed by a low median longitudinal ridge. This ridge merges with a pair of transverse elevations of moderate size at the major end of the plate, thus forming an inverted T in

* "Nothing corresponding to the plastron of *Dinichthys* and *Coccosteus,* composed of five distinct plates, has been found associated with the other bones of *Titanichthys,* but instead, a single large triangular plate, which may have been its representative."—*Newberry, J. S.,* Palæozoic Fishes of North America (Monogr. U. S. Geol. Survey, No. XVI. 1889). p. 132.

† Plate XL, Figure 1. "Ventro-median plate?"

relief. As seen from the ventral aspect, the form is suggestive of the nasal plate in *Dinichthys*, owing to the semicircular compression of the border around the head of the T. This plate was overlapped for three-fourths of its length by the anterior ventrals, as is also the case in *Coccosteus*.

Posterior dorso-lateral plate.—This element of the dermal skeleton is represented in the collection by three perfect specimens pertaining to the left side, and a fragmentary one from the right side. As already remarked, portions of this plate have long been known, Newberry having mentioned it as early as 1875.* The greater portion of two such plates is figured by the same author in his Monograph† under the designation of "post-clavicular (?) plates." In the body of the work (p. 142) this element is described as a "triangular bone with which I have long been familiar, but I am not yet able to fix with certainty its position on the body."

Newberry suggested two places where this bone might have fitted on: one behind and overlapped by the suborbital plate, the other somewhere between the median dorsal and the antero-dorso-lateral ("suprascapula"). This latter position he regarded as the more probable, although hesitating to express himself decidedly on this point. If the true relations of the plate had been clear in Newberry's mind, he would have designated it by its right name in the letterpress, and would not have styled it the "post-clavicular" in the legends for Plate VI.

A study of the material in the Museum of Comparative Zoology has convinced the writer of several things, as follows: The specimens figured by Newberry are incomplete, over 20^{cm} being wanting from either end; the "free margin" is not straight, but gently arcuate from end to end, and is indented for a certain portion of its length by a contiguous plate (postero-lateral); the surface is not plane but warped, and on the under side it is thrown into a few parallel undulations, the axes of which are transverse with respect to the main axis of the body when the plate is oriented in its natural position.

The plate in question is the *postero-dorso-lateral*. Newberry's figures 2 and 2a of Plate VI. are rights and lefts respectively;‡ to bring them into their natural relationships it is necessary to rotate them about their centers until their upper (anterior) extremities are inclined toward one another at an angle of about sixty degrees, and then separate them at a distance equal to the width of the median dorsal shield. In this position it will be noticed that the regular curve of the

* Palæontology of Ohio, vol. ii, p. 32.

† *op. cit.*, Plate VI., Figures 2, 2a.

‡ These relations are reversed by Newberry; hence the figures must be interchanged in position after they have been rotated so as to include the angle above specified between their free margins, which are here represented as parallel.

postero-lateral margin of the median dorsal, and the curve of the overlapped margin on the lower portion of the plate under discussion will fall together, on superimposing the one upon the other. The prolongation of this curve is observable on the inner margin of the suprascapula, where the same is overlapped by the median dorsal. In other words, the superincumbent margin of the median dorsal leaves an impressed area on the antero- and postero-dorso-laterals, by means of which the relative positions of these three plates can be accurately determined.

On examining the postero-dorso-lateral, it will be noticed that the curve formed by the overlapping margin of the median dorsal is intersected nearly at right angles by another, longer, more ragged, and more deeply incised contour-line than the first; this marks the posterior boundary of the antero-dorso-lateral. The sensory canal system of the latter plate is continued on to the postero-dorso-lateral, sometimes as a single and sometimes as a double furrow, and furnishes another convenient clue to the orientation. The indented area already referred to on the so-called "free margin" of the plate was formed by the postero-lateral; and it is possible to reconstruct the form of the laterals from their imprints upon the plates annectant to them above and below, their curvature being indicated by the clavicles. It is to be hoped that by this means some of the unidentified plates existing in various museums may be recognized as the missing laterals.

From the above it will be seen that every plate present in the body armor of *Coccosteus* has its representative in *Dinichthys*, and that the conditions of overlap and underlap are the same in both forms.

Median dorsal plate ("*Dorsal shield*").—The configuration of the posterior ridge on the under surface of this plate is well shown in a number of specimens belonging to the Terrell and Allen collections, two of which show that its inferior extension is greater than has been supposed. A preparation of these particular specimens resulted in the exposure of a deep spoon-shaped cavity at the extreme end of the terminal process on its dorsal aspect. The concavity is slightly emarginate below, and is continued up the ventral side of the process in the form of two broad, shallow depressions, which rapidly become narrower and deeper, so as to form well-marked channels. These gradually disappear, however, after traversing the lowermost portion of the inferior keel for a considerable distance. Corresponding to the ventral furrows are two dorsal, which extend from the bowl of the spoon along the 'handle' as far as the posterior margin of the dorsal shield proper. Here the terminal process broadens out on either side, and its roughened or striated upper surface evidently served for mus-

cular attachment. In contrast to this, it should be noted that the surface of the spoon-shaped concavity is perfectly smooth.

The question naturally arises, what purpose could this terminal structure have subserved? Was it in relation with the muscular system of the body, or for the support of a movable dorsal spine, such as is found in the recent Siluroids, for instance? It is easy to believe that the hollow part of the posterior process just described served equally well either for the lodgement of a ball of muscle or cartilage, or for the reception of the articular base of a spine, while the deep furrows above and below were for the insertion of tendons. The nearly perpendicular slant of the axis of the concavity, its shape and size, and the smoothness of its walls, strongly suggest that a dermal spine was implanted in it; but as yet we have only negative evidence of the presence of these defences in *Dinichthys*. We might theoretically associate with this genus certain detached ichthyodorulites coinciding with it in distribution throughout the same horizon; but more than a mere correspondence of parts is necessary before giving credence to such a speculation. Hence we can only affirm that if the posterior process of the dorsal shield supported a spine or spines, we are ignorant of their nature.

On the other hand, we know that the paired fins of *Dinichthys* were more or less rudimentary; and the only means for changing the direction of motion in the vertical plane while swimming was by flexure of the hinder part of the trunk and tail. It is evident that muscles inserted along the posterior process of the dorsal shield, and continued down the back on either side of the neural arches, would on contracting produce an upward flexure of the caudal region, owing to the arched curvature of the body. The effect of such a flexure is equivalent to elevating the head, and would cause the fish to ascend; conversely, a depression of the head, or flexing the tail downward, would enable the fish to sink. For so ponderous a body as *Dinichthys*, a firm attachment and support for the musculature was essential, as well as means for holding the massive plates in position; and these requirements could have been abundantly supplied by the structure of the dorsal shield, supplemented by its relation with the neural spines.

Doubtless much light can be shed on these problems by a study of the musculature in the recent Siluroids. The writer is indebted to Dr. Samuel Garman for valuable information regarding this group of fishes, and for the opportunity of dissecting an alcoholic specimen of *Loricaria* from South America. The condition of the latter, however, although showing excellent skeletal details, was unfavorable for an investigation of the muscular system.

Museum of Comparative Zoology, Cambridge, Mass.

ART. VII. — *The Tertiary Floras of the Yellowstone National Park;* by F. H. KNOWLTON, of the U. S. Geological Survey.

IT has long been known that the Yellowstone National Park, in addition to its numerous interesting geological features, possesses what is probably the most remarkable fossil forest known, and an abundance of finely preserved fossil plants. The writer has been engaged, for the past year or more, in the careful study of this flora, and the present paper has been prepared for the purpose of calling attention to some of the more important geological and biological results. The full report, with descriptions of new species and illustrated by forty-five quarto-plates, will appear in a monograph of the U. S. Geological Survey.

The localities that have supplied the Tertiary flora are all located in the north-eastern part of the Park, in the vicinity of the junction of the Lamar River with the Yellowstone, and along the Lamar River for a distance of ten or twelve miles from its mouth. The first fossil plants obtained from that portion of the Park were brought back by the early Hayden Survey parties. They were submitted to Prof. Leo Lesquereux, and although few in number, the species were nevertheless sufficient to afford some indication of their age. Professor Lesquereux regarded the plants from Elk Creek and vicinity as indicating an Eocene age, and those from the well-known Fossil Forest on the west side of the Lamar Valley as closely allied to the Auriferous Gravels of California. It is a pleasure to state that this adumbration has been abundantly confirmed by the results of more searching study of a larger amount of material; but at the time Lesquereux's statement was made, the facts were so few that the suggestions were not regarded as conclusive, and as it was before careful, detailed geological work had been done, these now clearly-defined beds came to be grouped together under the somewhat non-committal term Volcanic Tertiary.

Although the geology of the region has been fully discussed by Mr. Arnold Hague in a preceding article,* it seems necessary for a satisfactory understanding of the problems requiring solution to set forth briefly the geological features characterizing this portion of the Park which have a direct bearing upon the remarkable flora found. In the first place, all the material constituting the beds, in which the Tertiary plants are imbedded, is of volcanic origin. According to the geologists, this material may be divided into two distinct periods of volcanic eruption which can be distinguished by their mineral composition.

* June number, p. 445.

The older series of these lavas has been designated as the early acid breccias and flows and the younger as the early basic breccias and flows. Both these series of rocks carry plant remains. In general, the matrix in which the plants are preserved is a fine-grained ash, probably deposited as a mud-flow, in places with the appearance of stratification and other indications of waterlain deposits; occasionally the material is much coarser and has the appearance of breccias mixed with fine sediments. The acid rocks are usually light in color, yellow, lavender, or gray, while the basic rocks which carry more iron are darker in color, frequently some shade of green or dark brown, passing over into black. In some instances, as might be expected with fine waterlain beds, the deposits in both series of lavas closely resemble each other, while the great mass of lava of the two bodies may be readily distinguished. The acid breccias, the oldest of the lava flows, rests in many places upon the upturned edges of Archæan and Paleozoic rocks. In most instances, the basic breccias either rest directly upon the acid rocks, or else the underlying rocks are not exposed. The acid breccias are found on both banks of the Yellowstone River, below the mouth of Elk Creek. Again, near the junction of Hell Roaring Creek with the Yellowstone River, on Crescent Hill and near the head of Tower Creek.

In the neighborhood of Lost Creek and on the northern end of Specimen Ridge, along the drainage of Crystal Creek, the basic breccias are known to lie directly upon the acid breccias. In these localities the flora has a distinct character of its own, and bears evidence of being younger than the flora from the acid breccias. The basic series of rocks is typified at the Fossil Forest and also at the cliff a short distance to the south and east of the Fossil Forest. They also occur on the east bank of the Lamar River between Cache and Calfee Creeks. All of these localities are characterized by their plant remains, and the following determinations of age seem fully warranted.

The Tertiary floras as above outlined are found to embrace 147 more or less satisfactory species. Of this number, 81 species, or over 50 per cent., have been described as new to science. With these must be placed eight forms that have not been specifically named, thus leaving 58 species that were before known, and upon which we must largely depend in the determination of the age of the various strata in which they are contained.

The study of these plants has brought out the fact that they may be naturally divided into three more or less distinct floras or stages. These divisions, as already hinted in the remarks concerning the geology of the beds containing them, correspond with the geological divisions based upon the petrographical characters of the rocks. The first or older flora from the acid

rocks embraces 79 species or forms; the second or intermediate flora has 30 species, and the third or younger flora, fro the basic rocks, embraces 70 species or forms. It further appears that 23 species or forms are common to two or more of these divisions.

The flora of the older or acid series will be first considered. Of the 79 species, 42 are either new to science or not specifically named, leaving 37 species having a distribution beyond the limits of the Park. These 37 species are distributed as follows: 17, or nearly one-half, are found also in the Ft. Union beds near the mouth of the Yellowstone; 5 each are found in the coal-bearing Laramie, Denver, and Livingstone beds; 9 in the Green River Group and 10 in the Auriferous Gravels of California. Of the species found in the Laramie, Denver and Livingston beds, not one is confined to these beds and the acid rocks of the Park, but they are such species as *Sequoia Langsdorfii*, *Juglans rugosa*, *J. Schimperi*, *Platanus Guillelmæ*, etc., that enjoy a wide geological and geographical distribution. The Ft. Union element in this flora is thus shown to be a very important one, and when the evident affinities of the new species are followed out, it becomes clearly the dominant element. It includes at least 12 species that have never before been found outside of the type locality. Among these are: *Sparganium stygium*, *Populus speciosa*, *Populus daphnogenoides*, *Ulmus minima*, *Ulmus rhamnifolia*, *Sapindus affinis*, *Sapindus grandifolius*, and *Cornus acuminata*. Some of these are represented by as many as two hundred individuals, showing that they existed in great abundance.

Upon this evidence the flora of the acid rocks is referred to the Ft. Union or lower Eocene.

It will be next in order to consider the intermediate flora, As already stated, this embraces 30 species, of which number 18 are regarded as new to science. Of the 12 remaining species having a distribution beyond the limits of the Park, 6 are found in the Auriferous Gravels of California. Only 2 species are common to this flora and the acid rocks below, and only 3 to the basic rocks above. The affinities of this so-called intermediate flora are not especially pronounced with either of the other series, but considering the number of species common to the Auriferous Gravels and also the affinities of the new species, it is found that the greatest similarity is with the upper series, and for these reasons this flora is regarded as Miocene but older than the Auriferous Gravels.

It now remains to consider the flora of the basic rocks and its relationships. The typical locality for this flora is the celebrated Fossil Forest and vicinity. It embraces 70 species or

forms, distributed as follows: 38 species new to science, 3 forms not specifically named, and 29 species having a distribution outside the park. Of these 29 species no less than 17 are found to be common to the Auriferous Gravels of California. These are such important and easily recognized species as *Aralia Whitneyi*, *Persea pseudo-Carolinensis*, *Laurus Californica*, *L. grandis*, *Magnolia Californica*, *Ficus sordida*, *Juglans Californica*, *Rhus mixta*, etc.

Besides the species above enumerated that have actually been found common to the two localities, the numerous new species are unmistakably related to species only known from the Auriferous Gravels. Thus one of the new magnolias is closely allied to *M. Californica*, and another is so close to *M. lanceolata* that it was so identified by Professor Lesquereux.

Other examples might be given but they are unnecessary in the present instance. The preponderance of evidence points to the similarity of age between the flora of the basic rocks and that of the Auriferous Gravels of California. In order to further characterize it, it may be called the Lamar flora from the river and valley along which the principal exposures occur. The age is regarded as upper Miocene.

When viewed from the biological side this Tertiary flora is found to present many interesting features. It is a rich flora, and on comparing it with the living flora it becomes apparent that great climatic changes must have taken place since the close of the Miocene period, to have made possible these changes in plant life. The fossil flora, as already stated, embraces 147 forms, that are distributed among 33 natural orders. Following is a list of these orders with the number of species or forms referred to each:

Filices 10.
Equisetaceæ 4.
Coniferæ 13.
Typhaceæ 1.
**Sparganiaceæ* 1.
Cyperaceæ 4.
Smilaceæ 1.
Musaceæ 1.
**Juglandaceæ* 8.
**Myricaceæ* 3.
Salicaceæ 11.
Betulaceæ 2.
**Fagaceæ* 15.
* *Ulmaceæ* 5.
Urticaceæ 10.
**Magnoliaceæ* 5.
**Lauraceæ* 11.
**Platanaceæ* 3.
Leguminosæ 5.
**Anacardiaceæ* 1.
* *Celastraceæ* 4.
Aceraceæ 2.
**Sapindaceæ* 5.
Rhamnaceæ 3.
* *Vitaceæ* 1.
**Sterculiaceæ* 1.
* *Credneriaceæ* 1.
* *Tiliaceæ*, 2.
**Araliaceæ* 6.
Cornaceæ 2.
Ericaceæ 1.
**Ebenaceæ* 3.
* *Oleaceæ* 1.
**Phyllites*, * *Carpites* 3.

The excellent *Flora of the Yellowstone National Park** by Mr. Frank Tweedy has been made the basis of all comparisons between the fossil and living floras. According to Tweedy the present flora embraces 69 natural orders, 273 genera and 657 species. The fossil flora embraces 33 orders, 63 genera, and 147 species. The living flora has therefore 4 genera to each order and 2·4 species to each genus, while the fossil flora has not quite 2 genera to each order and 2·3 species to each genus. The relative proportion between the orders, genera and species is shown to be approximately the same in the living and Tertiary floras. A still further comparison shows that there are a fraction more than twice as many living as fossil orders, 4·3 times as many living genera and 4·6 times as many species.

On comparing the orders in the two floras it is found that 19 of the 33 fossil orders are not represented in the living flora.† It is found that such important orders as the Juglandaceæ, Fagaceæ, Ulmaceæ, Magnoliaceæ, Lauraceæ, Platanaceæ, Anacardiaceæ, Celastraceæ, Vitaceæ, Sterculiaceæ, Tiliaceæ, Araliaceæ, Ebenaceæ, and Oleaceæ, are not represented in the present flora. In other words there are no walnuts, hickories, oaks, beeches, chestnuts, elms, magnolias, sycamores, sumacs, grapes, lindens, azalias, persimmons, or ashes at the present day.

The dominant elements in the living flora are the abundant coniferous forests, yet only eight species are present and of these only five are at all common, and 65 per cent. of the whole coniferous growth is made up of one species (*Pinus Murrayana*). The fossil flora is represented by thirteen species, or nearly twice as many as the living. Among them was a magnificent Sequoia that was closely allied to the living *Sequoia sempervirens* of the Pacific coast. It had trunks ten feet in diameter, and there are indications that they were of great height. There were also two well-marked species of Sequoia known from the leaves and a number of supposed Sequoia cones. The pines were in abundance, no less than seven species having been detected. Of these two are known from the leaves, three from beautifully preserved cones and two from the internal structure of the trunks.

The living deciduous-leaved trees and shrubs of the Yellowstone Park are conspicuously few in number. There are two species of Betula, two of Alnus, seven of Salix, two of Populus, one of Acer, four of Vaccinium, five of the order Caprifoliaceæ, two of Cornaceæ, two of Rosaceæ, etc. Perhaps the most conspicuous tree is the quaking aspen (*Populus tremu-*

* Wash., 1886, pp. 1–78.

† In the list of orders given above those not represented at the present day are marked with an asterisk.

loides). The cotton wood (*P. angustifolia*) is rare, being found in only one locality, according to Tweedy. Several of the willows are abundant, as is also the common birch of the region (*Betula glandulosa*), and the June-berry (*Amelanchier alnifolia*). The other shrubs are either rare or confined to few localities.

The fossil flora, on the other hand, was especially rich in deciduous-leaved vegetation. Thus the Juglandaceæ was represented by five species of Juglans and four species of Hicoria (Carya), a number of which were very abundant.

The genus Populus was particularly rich, there being no less than seven species. Certain of these, as *Populus speciosa*, *P. glandulifera*, and *P. daphnogenoides*, were in great abundance, and the stratum in which they occur consists of a perfect mat of these leaves. Something over one hundred examples of one of these species were obtained.

Another striking feature was the presence of numerous magnificent Magnolias; of these four species have been described from the leaves and one from the thick petals of the flower. One of the new species, represented by a great number of leaves in a fine state of preservation, appears to be more closely allied to the living *M. fœtida* (*M. grandifolia*) than any previously described.

The sycamores were also an important element in this flora. Of the two species described from the leaves and one from the wood, the one known as *Platanus Guillelmæ* was especially abundant. It is found in nearly all of the Tertiary beds in the Park, and is represented by nearly two hundred examples. The species described from the wood is based upon a trunk about one foot in diameter and is most closely allied to the living *P. occidentalis*.

Another important group is formed by four species of Aralia. Of these *Aralia notata* was evidently the most abundant and imposing plant of the whole flora. The collections contain over one hundred specimens. None of them are preserved entire, but there is abundant evidence to show that some of these leaves must have been fully three feet in length and more than two feet in width. *Aralia Whitneyi*, a species common to the Auriferous Gravels of California, had striking five to seven-lobed leaves often one foot in length. This species was not as abundant, judging from the fossil remains, as the former species, but it was apparently quite widely distributed. The other species had smaller three or five-lobed leaves.

The Lauraceæ was strongly represented by five genera, eleven species, and a large number of examples. The genus Laurus, which is now exclusively an old world form, was represented by six well-marked species. The genera Litsea and

Cinnamomum, other old world forms, were both represented, the former by two and the latter by one species. The genus Persea was also represented by a single species.

Another large and important group, now entirely unrepresented in the Park, is the Fagaceæ, embracing two species of Fagus, one of Castanea, eleven of Quercus and one of Dryophyllum. The Fagus described as new is a beautiful characteristic leaf, evidently rare, as it is found in only one place. The Castanea, on the other hand, was very abundant and widely distributed within the Park. The leaves are large and as handsome and striking as are the leaves of the common living species (*C. dentata*). The oaks, however, were abundant in species and usually in individuals. They are all but three new to science.

The Urticaceæ, which are represented in the living flora by a single rare herb (*Urtica gracilis*), was represented during Tertiary times by some ten species of Ficus and a single more or less doubtful species of Artocarpus. Only two or three species of Ficus were particularly abundant, at least as evidenced by their fossil remains. It is of great interest to learn, however, that they were once present in a region that has long since ceased to support them. The curious leaf referred provisionally to Artocarpus is also of much interest as indicating the possible presence of the bread-fruit tree in this portion of the American continent. Two unmistakable species of Artocarpus have already been detected; one from the Laramie and Denver beds of Colorado, and the other from the Auriferous Gravels of California and the Miocene of Oregon.*

It is therefore not improbable that the type was in existence in the Yellowstone Park during the early Tertiary.

The Leguminosæ, now represented by a host of small herbaceous plants, was then represented by three species of Acacia, known from pods, and two of Leguminosites, known from leaflets. But none of them is particularly satisfactory.

The only remaining group of deciduous-leaved plants of any magnitude is the Sapindaceæ with five species of Sapindus. Of these *Sapindus affinis* is perhaps the most abundant form found among the Tertiary plants of the Park. The small characteristic leaflets are found in the greatest profusion. The other species were less abundant.

The other forms that require mention are Ulmus with four species, Acer with at least two species, Celastrus with three species and Rhamnus, Paliurus, Zizyphus, Cissus, Pterospermites, Tilia and Rhus with a single species each.

* Science, vol. xxi, p. 24, 1893

The cryptogams appear to have been a much more prominent floral feature during Tertiary times than now. Of the two orders present, the Filices and Equisetaceæ, the former is represented by ten and the latter by four species, while the living flora has but six ferns and four horsetails, all of which are rare.

The ferns were abundant. They belong to six genera and are represented in several cases by a large number of specimens. The largest genus is Asplenium with four species. One of these that has been described as new is perhaps the largest and finest that has been detected outside of the Carboniferous, at least in North America. The genus Aspidium is represented by two species, both of which appear to have been rare. They are, however, both fruiting, a condition of uncommon occurrence among fossil forms. There is also a fine Woodwardia that appears to be quite closely allied to a species now living in the eastern United States, and beautifully preserved examples of the widely distributed climbing fern (*Lygodium Kaulfusii*). It is very similar to the only living North American species *L. palmatum*. The other ferns are an Osmunda and a delicate form referred provisionally to the genus Davallia.

The genus Equisetum, although represented by four more or less satisfactory species, was not abundant or particularly important. The commonest form is small and has much the appearance of the living *E. limosum*.

From what has been presented, it is obvious that the present flora of the Yellowstone National Park has comparatively little relation with the Tertiary floras, and can not be considered as the descendant of it. It is also clear that the climatic conditions must have greatly changed. The Tertiary flora appears to have originated, or at least to have had its affinities at the south, while the present flora is evidently of northern origin. The climate during Tertiary time, as made out by the vegetation, was *apparently* not unlike that in some parts of the southern United States at the present day.

It would be of interest to describe the remarkable fossil forests of standing trunks, but their consideration must be deferred to the final report.

ART. VIII.—*A New Belodont Reptile* (STEGOMUS), *from the Connecticut River Sandstone;* by O. C. MARSH. (With Plate I.)

THE red sandstone of the Connecticut valley has long been famous for its footprints, especially the so-called "bird tracks," which are now very generally believed to have been made by Dinosaurian reptiles. These strata, however, like most deposits of similar physical character in other parts of the world, contain few osseous remains, and those discovered here, almost without exception, belong to carnivorous Dinosaurs of Triassic types, as the writer has shown elsewhere.

The *Belodontia*, one of the most characteristic groups of Triassic reptiles, are almost unknown in the Connecticut river sandstone, a single specimen only having been discovered, and recently named by the writer *Belodon validus.** No footprints that can be referred to this order of reptiles have yet been found among the thousands brought to light in this region, although a careful search for such impressions has long been maintained, especially in the horizons where they were most likely to be preserved.

During the past year, a noteworthy discovery has been made in the Connecticut sandstone, within the city limits of New Haven, and it is the main object of the present paper to place this discovery on record, both on account of its local interest and its scientific importance. The specimen found is represented in the accompanying plate, one-third natural size. The fossil shows the impression of the dermal armor of a large reptile, which apparently represents a new genus of the *Belodontia*. The dermal covering thus preserved is mainly from the dorsal region, although the anterior part protected the back of the neck. No other portions of the dermal armor nor any of the skeleton were found, although a careful search was made at the time of the discovery and subsequently, both at the locality itself and in the vicinity. It is therefore probable that the dermal covering here described was torn from the animal after death and before entombment in the coarse sand and gravel then deposited by a strong current, as indicated by the present structure of the sandstone.

In the fossil represented in the accompanying plate, the dorsal region of the reptile is shown, with the anterior portion to the left. The median dorsal line is indicated by the narrow longitudinal ridge, placed nearly horizontal in the figure. In the cervical region, this nearly straight line is broken,

* This Journal, vol. xlv, p. 170, February, 1893.

as the armor was here turned slightly to the right and somewhat twisted. This median ridge was formed by the matrix filling the narrow space between the ends of the dorsal plates, where they met in pairs on the median line. The transverse ridges are likewise due to the filling in of the matrix between the adjoining plates, which evidently were somewhat separated by connecting tissue admitting of more or less motion, but which held the whole dorsal armor together as a carapace.

The large median plates indicated in this fossil are twenty in number in each of the two rows meeting on the middle line. These plates are elongated transversely, strongly convex, and their form is accurately shown in the figure. Their inner extremities are nearly at right angles to the sides, but the outer ends are oblique where they join the plates of the lateral series, or second row. These lateral plates were quite short, and their form and position are clearly preserved in the specimen figured. All the dermal armor indicated resembles, in its general features, the corresponding portions in the genus *Aëtosaurus*, Fraas, from the upper Trias of Germany. In the latter, however, the plates are imbricate.

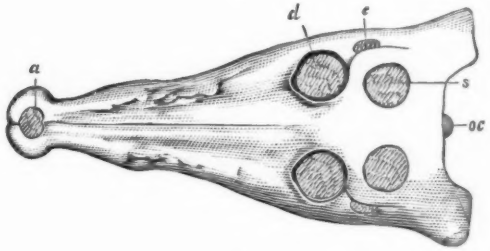
The above description is based upon the impressions left by the inferior side of the plates upon the plastic matrix in which they were imbedded. The plates themselves have since disappeared, having been dissolved by infiltrating waters. The cast of the superior surface of the plates was of somewhat softer material than the matrix below, and most of it was lost in removing the specimen. The portions recovered show that the upper surface of the plates was rugose, but not deeply sculptured, being less marked in this respect than in the other known species of Belodonts. The rough surface preserved shows no regular pattern of ornamentation, and there are no indications of a crest on the plates. The form and position of the plates are characteristic features, and as both the genus and species appear to be distinct, the reptile may be known as *Stegomus arcuatus*. The animal when alive was of moderate size, probably eight or ten feet long. This would be about two-thirds the size of *Belodon validus*, the scapula of which is eight and one-half inches in length. The fossil here described indicates an animal with a body capable of some lateral flexure and considerable vertical movement. The type specimen was found by F. P. Clark, and presented by D. A. Van Hise to the Yale University museum.

Outside the Connecticut valley, remains of *Belodontia* have been found at several points in this country. Some of the best known were discovered by Prof. Emmons in the Triassic of North Carolina, most of the specimens having been obtained in the Deep river coal mines. One of these fossils is the skull figured by him under the name *Rutiodon Carolinensis*.*

* Manual of Geology, p. 179, 1860.

The genus is a distinct one, the characters now known separating it widely from *Belodon* of von Meyer, from the Keuper of Würtemberg. This is indicated in figures 2 and 3, below.

1.



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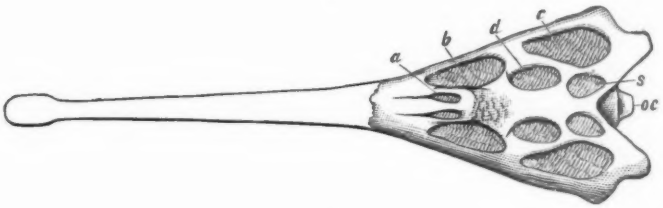


3.

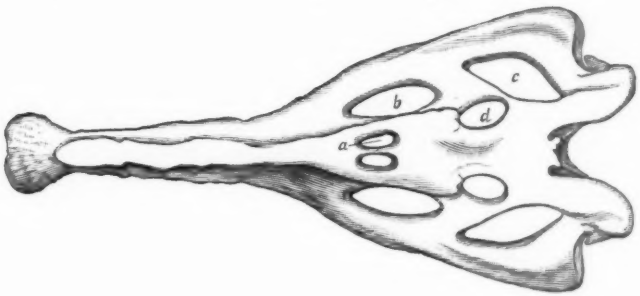


FIGURE 1.—Diagram of skull of *Diplosaurus felix*, Marsh.
FIGURE 2.—Diagram of skull of *Rhytidodon rostratus*, Marsh.
FIGURE 3.—Diagram of skull of *Belodon Kapffi*, von Meyer.
a, nasal aperture; *b*, antorbital opening; *c*, infratemporal fossa; *d*, orbit; *oc*, occipital condyle; *s*, supratemporal fossa.
Figure 1 is one-fourth, and figures 2 and 3 are one-eighth natural size.

The diagram of the skull of *Belodon* shows that the supratemporal openings, characteristic of the true crocodilians, are wanting, while in the genus *Rhytidodon* (*Rutiodon*), they are present, and in their usual position. The fluted teeth of

the latter genus are different from those of *Belodon*. Figure 1 shows the skull of *Diplosaurus*, a crocodilian from the Jurassic of Colorado. The superior nasal aperture (*a*) is in front, as in existing crocodiles, while in the Belodonts, as shown in figures 2 and 3, these openings are far back in the upper part of the skull. Figure 2 represents a new species, found by J. B. Hatcher in the Triassic of North Carolina. In this specimen, the quadrate slopes forward, and not backward as in the *Crocodilia*.

Other fossils of apparently the same group have been found in Pennsylvania, and described by Lea under the generic name *Centemodon*, and by Leidy, as *Omosaurus*. Still others were described later by Cope, from both Pennsylvania and North Carolina, and more recently some from the Triassic of New Mexico, which received the names *Typothoræ* and *Episcoposaurus*. Nearly all the above specimens are so fragmentary that it is at present difficult, if not impossible, to determine their exact relations to each other.

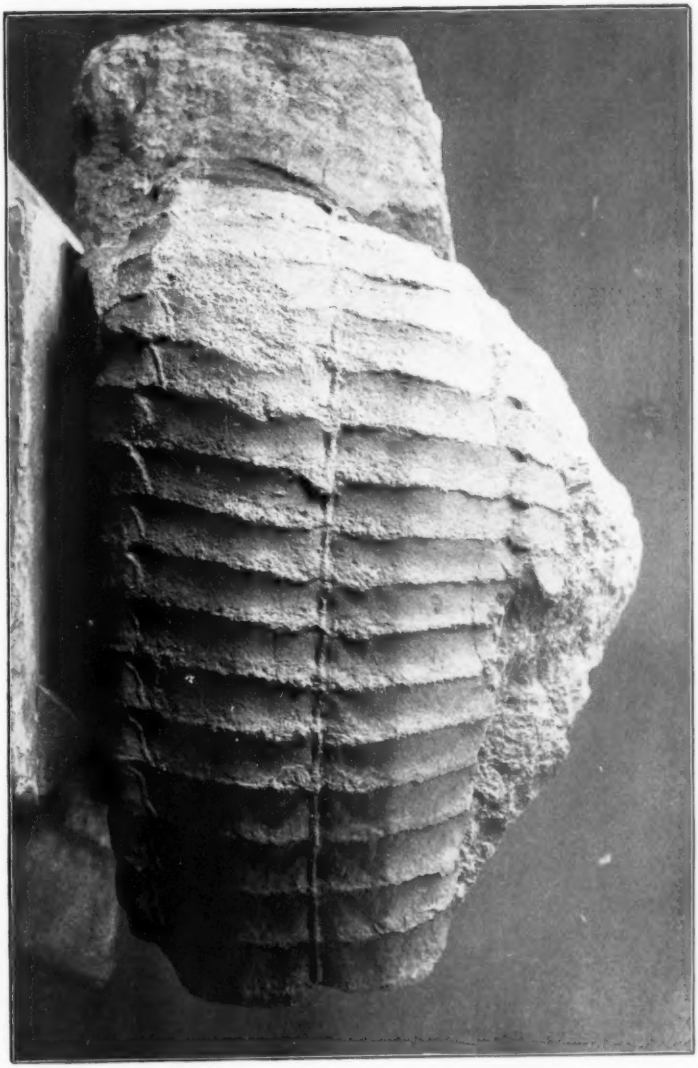
The difficulty in this case is practically the same as that which has occurred time and again in separating fossils found together at other localities, especially where genera of reptiles have been based upon isolated teeth, which, unlike those of mammals, have so often proved unreliable. In the original locality of *Belodon*, near Stuttgart, in Germany, remains of carnivorous Dinosaurs (*Zanclodon*) also occur, while Labyrinthodonts are still more abundant, all represented by species of approximately the same size. The fragmentary remains of these, when mixed together, have led to much confusion, as the many names proposed for them demonstrate. After various well-preserved specimens were studied, the separation of the Labyrinthodonts, even in isolated remains, became a comparatively easy matter, but the Belodonts and Dinosaurs, being more nearly allied, have hardly yet found their proper places.

Precisely the same thing occurred when the rich North Carolina localities of nearly the same horizon were first explored. The Belodonts, Dinosaurs, and Labyrinthodonts were all there, with their fragmentary remains commingled in a still more indiscriminate manner. This was in part true, also, of the Pennsylvania localities, and those in New Mexico have likewise contributed their share to the general confusion. The discovery of more perfect specimens will doubtless gradually remove the obscurity now existing as to the strange vertebrate fauna of this extensive horizon.

Yale University, New Haven, Conn., June 5, 1896.

EXPLANATION OF PLATE I.

Impression of dermal armor of *Stegomus arcuatus*, Marsh. One-third natural size. From the Triassic sandstone, New Haven, Conn.



STEGOMUS ARCUATUS, Marsh. One third natural size.

Art. IX.—*On Separation, and its bearing on Geology and Zoögeography;* by Arnold E. Ortmann.

In a recent publication* I pointed out the importance of the principle of *separation* or *isolation* as regards the distribution of animals as well as the origin of species. The present article intends to give a short review of the views set forth in the book referred to, especially regarding the geological and palæontological aspect of the matter.

While some authors believe that *natural selection* is sufficient for the explanation of the origin of species, and that "the mode of formation of the living world as a whole" (Weismann) can be understood by his principle, I maintain, on the contrary, that natural selection is only one of the factors coöperating in the formation of species, and especially, that it acts only in a particular line, namely effecting a slow transformation of existing species. In the book referred to (p. 31) I have shown that by natural selection only a transformation of one already existing species into one other species is possible, but that it is impossible to think that two or more different species originate from one original species by selection. The transformation of species in time is entirely different from the differentiation into several contemporaneous species. The former process, well known to palæontologists under the term "mutation" (Waagen, Neumayr, Scott) has been generally not properly understood by biologists, and I cannot enough emphasize, that mutation of one species in time should not be confounded with differentiation into coexisting species.

As I have demonstrated (l. c., p. 31), the latter process is due to the factor called by M. Wagner separation or isolation, and although this principle has been discussed by many subsequent authors, it has been—with few exceptions (G. Baur)—generally misunderstood or not accorded its full value, since most authors have conceived it only in a purely geographical sense. Yet in nature we have not only a purely geographical separation, but many other causes may have the same effect. Generally we may say, that any causes which induce certain groups of animals to live under particular conditions of existence, while other related groups are not subject to the same conditions, in other words, that any causes effecting a permanent interruption of the bionomical continuity between certain groups, come under the head of the term separation. Separation keeps particular groups permanently under particular conditions, and

* Grundzüge der marinen Tiergeographie, Jena, 1896.

thus they are prevented from migrating from one station of definite conditions of life into others with other conditions.

Separation has acted since the beginning of the geological history of organic beings upon their differentiation into species. In the most remote geological periods we can distinguish particular parts having each different conditions of existence. The most general differentiation is created by the existence of particular life-districts:* districts of different primary conditions of life. The chief differences (l. c., p. 18) are made up of the conditions of the light, medium, and substratum, and according to the different features of these three conditions I have distinguished as follows:

1. Light. The medium is air. Substratum present.—Terrestrial district.
2. Light. The medium is fresh water. Substratum present. —Fluvial district.
3. Light. The medium is salt water. Substratum present. —Littoral district.
4. Light. The medium is salt water. Substratum wanting. —Pelagic district.
5. Dark. The medium is salt water. Substratum present.— Abyssal district.

These are practically the most important life-districts, and, as a rule, every form of animal life is restricted to one of them. But there are a few exceptions, that is to say, sometimes certain animals migrate from one district into another: such changes, however, are regular ones, and are governed by strict laws. Any artificial or unnatural transplantation of a species from the proper life-district into another involves the impossibility of its farther existence.

Life-districts have existed since dry land rose above the surface of the ocean. It is generally accepted, that first an ocean of an equal (but considerable) depth covered the whole surface of the lithosphere, and subsequently, by the subsidence of certain parts of the latter, and by the compensating upheaval† of other parts of the earth's crust, greater depths of the ocean were formed, and parts of the lithosphere rose above the sea-level. As soon as this was accomplished, the five different life-districts were present. I have shown further (l. c., p. 39), that the topographical continuity of each of these life-districts is different, and especially, that during the geological development of the earth the external limits of each changed in a considerable degree (l. c., p. 64): continuous parts were separated, and separated parts connected. These changes are most conspicuous and important in the terrestrial, fluvial, and littoral

* "Lebensbezirke," see l. c., p. 15.
† I differ in this respect from Süss' opinion.

districts, while the pelagic and abyssal maintained during all the geological part their continuity, and are still at present perfectly continuous topographically. This continuous change, especially within the littoral district, during the different geological periods is very remarkable. No doubt, these changes take a considerable part in developing a great diversity of species.

But not only the differences of the life-districts and their topographical features effect separation of the inhabitants, but within each life-district, independently from the topographical continuity, separate parts are present. I refer to the differences of what is called facies (l. c., p. 23). Although the differences of facies are first recognized by geological science, and although it is well known that the living as well as the fossil organisms are influenced in a considerable degree by the facies, and are adapted to and dependent on particular facies, this factor, I think, is not yet considered properly in palæontology. In papers discussing the different faunas of the same geological period, differences of the fossil remains found in strata of apparently the same age, are often attributed to separation of the respective sea-basins by land,* as the only means producing a different development of species in the seas thus separated: but separation by differences of facies may induce the same process. Palæontologically and geologically, it is a well known fact, that certain groups of animals prefer particular facies, but we have no definite proof yet, that different but nearly allied species are found in different facies, and in most cases we do not, or only incompletely, know the particular conditions under which the different beds were deposited.

We see often that in the geological succession one facies is replaced by another, and very often we see that the imbedded fauna becomes entirely different accordingly. In other cases, however, we have in an overlying bed apparently the transformed descendants of the underlying fauna, and lastly, I wish to direct attention to a fact, which appears at first strange, namely the reappearance of an older fauna in younger strata.† It may be possible that such cases are due to a change of facies: the original facies and its peculiar fauna are replaced in a particular locality by another facies with its fauna, but later on the first occupied this locality again, and the old fauna reappeared.

* I refer for example to a recent paper of Weller: A circum-insular Palæozoic fauna.—Journ. Geolog., Chicago, iii, 8, 1895, p. 903–927. I do not wish to criticise this very important article as regards the results obtained, but only to suggest, that the differences of facies certainly present in the localities discussed should be considered also.

† Compare Barrande's "colonies" in the Silurian strata of Bohemia, and H. S. Williams' paper entitled: The recurrence of Devonian fossils in strata of Carboniferous age, this Journal, xlix, 1895.

It is obvious that in this respect there is an ample field of research left unoccupied. Although the geological development of many groups of fossil animals in the successive strata has been investigated, no attention is directed to the influence of the conditions of life upon the single forms, and the influence of separation of these conditions upon the differentiation of particular directions of development. The extant investigations treat the matter from a mere systematic and phylogenetic standpoint, referring only to the stratigraphical conditions, but the facts of geographical distribution, and especially of bionomic relations, that is to say, the relations to the general conditions of life, are mostly neglected. Of course, such studies as are desired here are very difficult, especially because the exact synchrony of the zoölogical facies deposited in different localities is often uncertain; but it would be very desirable to collect carefully all the facts relating to these questions, in order to secure material for a study of the mutual relations of the different facies in time and space. Thus, I hope, it will be possible, not only to trace particular species in their development through different zones, but to understand their successive mutations and differentiations into separate species, at least within smaller periods of the geological history of the earth, and the study of palaeontology may demonstrate, that separation is a continuously acting factor in the formation of species, and may support my opinion, that it is that particular factor which causes the differentiation of species.

In more recent geological times another factor causing separation is added: the climatic differentiation of the surface of the earth. I have demonstrated (l. c., p. 40) that this factor most especially effected the breaking up of the old and more or less continuous life-districts into zoögeographical provinces. While the terrestrial and fluvial districts have been characterized since the beginning of their existence by discontinuity, the continuity of the marine districts has been interrupted in a peculiarly complicated manner since the introduction of climatic changes, which began in the earliest Tertiary period.† For zoögeographical studies I have divided (l. c., p. 45–60) those parts of the earth which are occupied by the oceans into the following regions:

I. Littoral life-district.

1. Arctic region. 2. Indo-Pacific region. 3. West American region. 4. East American region. 5. West African region. 6. Antarctic region.

* In a paper published recently (this Journal, April, 1896) I have demonstrated, that Neumayr's theory of the existence of climatic zones in Jurassic times is without a proper foundation. I may add here, that the same opinion (that climatic changes did not begin until the Tertiary time) is set forth recently by Dubois (The climates of the geological past, 1895).

II. Pelagic life-district.
1. Arctic region. 2. Indo-Pacific region. 3. Atlantic region. 4. Antarctic region.

III. Abyssal life-district.
No regions distinguishable.

It is very remarkable that it is impossible to distinguish any regions in the abyssal district. As this whole district is characterized by a low and very nearly constant temperature, no climatic zones can be distinguished, and further, as this whole district is continuous throughout its extension over the bottom of the oceans, no topographical divisions are present. Therefore we cannot establish any zoögeographical regions within this district, which agrees with the well-known fact that most of the true abyssal animals have a world-wide distribution.

But even in the Tertiary period the limits of the zoögeographical regions of the littoral and the pelagic districts were often very different from those of the recent time, because the topographical features of the seas were different. As the most important difference should be regarded the continuity of the circumtropical belt maintained during a great part of the Tertiary. This continuity was due to the well-known fact, that the connection of North and South America was not yet formed, and, perhaps, that there was present a communication of the southern European seas with the Indian Ocean. The separation of the Mediterranean Sea from the Red Sea and the Indian Ocean, and its connection with the Atlantic Ocean, and especially the separation of the Pacific Ocean from the West Indian seas by the rising of the Isthmus of Panama, were the last steps accomplishing the development of the recent conditions, and the latter are, geologically speaking, of a very recent date: they were not formed until the second half of the Tertiary period.

It is very interesting, that the present geographical distribution of many animals points often and clearly to the former conditions existing a comparatively short time ago, and the geographical distribution, if regarded under the principle, that species are formed by separation, may give us some hints as respects the former geological and geographical conditions. It may be well here to indicate some principles worthy of notice.*

*I have myself endeavored to apply the following principles in a series of monographs discussing the distribution of smaller groups of Decapod-Crustaceans. As regards the influence of external conditions, climate, facies, etc., upon the distribution of species in a particular locality, I should like to refer to a most valuable work published by Petersen (Det Videnskabelige Udbytte af Kanonbaaden "Hauchs" Togter, 1893, p. 433–464). It would be very advantageous for science if investigations of this kind were made more extensively.

1. Each species must have originated in a separate locality (center of origin).

2. It is very improbable that the same species originated twice in different and separated parts of the earth.

3. The same species existing in completely separated localities indicates a former connection, which, as a rule, lies not far back in time.

4. Nearly allied species in separated localities indicate a former connection, but in a more remote time. The degree of relation may give a rough estimate of the relative time that has elapsed since separation.

5. Formerly separated parts of the earth's surface are difficult to locate, since a later connection destroys the differences that existed formerly, and the animals peculiar to each separate part cannot be recognized.

I may add, that palæontological research may find out, and indeed in some cases has already found out, examples of the latter kind,* since the peculiar fauna of an isolated locality can be preserved in fossil state.

I think I have sufficiently demonstrated, that the principle of separation not limited to a strictly geographic sense, but enlarged, and understood generally as a bionomical principle, is not only important as regards the origin of species, but also as regards geographical distribution, palæontological and geological history of animals. Bionomic separation means that it is essential for separation, that the groups of animals separated from each other are subject to different conditions of life, and I emphasize this point as the chief peculiarity which effects a differentiation of the characters of animals inhabiting different stations. We can imagine a purely geographical (topographical) separation with the conditions of existence remaining unaltered in the separated parts: then a differentiation of species does not result, and the original species continues to exist without a change. We know many examples of this kind, that an identical species is found in separate localities, and I have called (l. c., p. 34) such species relics from a former continuous distribution.

I think, everybody who has ever undertaken to study the origin of species will agree with the views set forth here, at least as regards the insufficiency of natural selection for the differentiation of species, and everybody will concede, that *transformation or mutation* of a species is fundamentally different from differentiation into coexisting species, and that in this respect Weismann's opinion, that natural selection may explain "the mode of formation of the living world as a

* For example: Neumayr in the Cretaceous and Jurassic periods, Mojsisovics in the Triassic, and recently Weller in the Devonian period.

whole," is utterly unwarranted. Natural selection can never explain the divergence of the directions of mutation, that is to say, the origin of separate forms from one ancestral form: this is only conceivable if we introduce the principle of separation. But further it will be remarked, that I lay much stress upon the transforming power of the external conditions of life, and that I differ also in this respect from the theories propounded by Weismann, who does not believe, that external conditions are able to affect the body of organic forms so that the changes thus produced may be transmitted to descendants and give origin to a change of the specific characters. In this respect I may mention here, that I am a decided opponent to Weismann's theories as a whole, and that I consider them to be illogical and contrary to the known facts, which is—in my opinion—amply demonstrated already by Pfeffer and O. Hertwig. I refer only to these critics among the large number of Weismann's adversaries, especially since Pfeffer* has engaged himself in demonstrating the logical contradictions of Weismann, and O. Hertwig† in demonstrating the contradictions of Weismann's theories to the facts. Perhaps, I shall find opportunity to contribute to the criticism of Weismann's theories elsewhere: it may be sufficient here to say, that I cannot accept Weismann's theories of the origin of variations, and accordingly, that I must stick up for the old "working hypothesis," that variations are produced by the surrounding conditions, and that these variations may be transmitted.

Princeton, N. J., March, 1896.

*Die inneren Fehler der Weismannschen Keimplasma-Theorie.—Verhandl. Naturwiss. Ver. Hamburg (3) I. 1894.

†Zeit- und Streitfragen der Biologie., Heft 1, Präformation oder Epigenese, Jena, 1894.

Art. X.—*An Iodometric Method for the Determination of Carbon Dioxide;* by I. K. Phelps.

[Contributions from the Kent Chemical Laboratory of Yale University.—LI.]

In a recent paper from this laboratory,* it has been shown that carbon dioxide may be estimated with accuracy by absorbing it under prescribed conditions in barium hydroxide, washing away the excess of the hydroxide, and converting the precipitated carbonate to the form of the sulphate. The chief difficulty in the process was occasioned by the fact that the barium carbonate precipitated from cold solutions is so finely divided and non-crystalline in character, that the removal of the excess of the hydroxide by filtration is a somewhat delicate and tedious process. The possibility of taking up by iodine the excess of the hydroxide remaining after the precipitation of the carbonate, and then determining the excess of iodine volumetrically, furnished the incentive to the following experiments.

The process, as finally developed, consists of three steps: first, the evolution of the carbon dioxide and its collection in barium hydroxide contained in a partially evacuated flask; secondly, the conversion of the excess of the hydroxide to the form of iodide and iodate by adding an excess of iodine; and thirdly, the titration of the excess of iodine with standard arsenious acid.

The barium hydroxide solution was prepared for use by filtering a cold, saturated solution into a large bottle, from which it was drawn, or pumped by means of the little improvised pump described by Kreider;† in either event care was taken to feed the air, which took the place in the bottle of the hydroxide removed, through potash bulbs to prevent the introduction of atmospheric carbon dioxide. The solution of barium hydroxide was standardized by drawing 80—90 cm.^{3} of decinormal iodine into a glass flask, provided with a ground-glass stopper carrying an inlet tube reaching nearly to the bottom of the flask and an outlet tube to which was sealed a Will and Varrentrapp absorption apparatus, and then introducing an appropriate amount of the barium hydroxide solution either from a burette or from a stoppered funnel which was weighed before and after. An ether wash bottle answers admirably for a standardizing flask, and with the glass stopper and its attachments replaced by a rubber stopper,

* This Journal, I, 101. † Ibid., I, 132.

answers the purpose of the absorption flask described later. The glass stopper is introduced, the inlet being closed by a rubber cap, and the absorption apparatus is charged with a solution of potassium iodide, to hinder the escape of iodine. The solution was brought to a boil, then cooled and the excess of iodine determined by decinormal arsenious acid. It is assumed that the iodine lost acted on barium hydroxide according to the equation:

$$6BaO_2H_2 + 6I_2 = Ba(IO_3)_2 + 5BaI_2 + 6H_2O.$$

It was found necessary to boil the solution because of the formation of traces of the hypoiodite, which is broken up into iodide and iodate only by boiling, but which, if left unchanged, acts subsequently on the arsenious acid used in titrating the free iodine.

The apparatus which I have found most convenient for evolving the carbon dioxide from the carbonate consisted of a wide-mouthed flask of about 75 cm.^{3} capacity, furnished with a doubly perforated stopper carrying a separating funnel for the introduction of acid into the flask, and a tube of 0·7 cm. internal diameter, which is expanded to a small bulb just above the stopper, to carry off the gas. This exit tube was joined by a rubber connector to a tube which passed through the rubber stopper, closing the absorption flask (the ether wash bottle used in standardizing the barium hydroxide solution described above), and which ended in a valve preferably of the Kreider pattern.* This valve was enclosed in a larger tube reaching nearly to the bottom of the absorption flask. Through a second hole in the stopper of the absorption flask passed a glass tube closed by a rubber connector and screw pinch cock.

In making a determination of carbon dioxide, the carbonate was introduced in weighed portions into the boiling flask. Barium hydroxide solution, in amount from 7–10 cm.^{3} more than actually necessary to precipitate the carbon dioxide, was drawn into the absorption flask, which was then connected with the boiling flask, as described above. The stop-cock of the separating funnel was shut off and the flasks evacuated by connecting the exit tube of the absorption flask with a filter flask previously pumped out by the water pump, a mercury manometer registering the pressure. Exhaustion to a pressure of from 250–300 mm. was found sufficient and easily attainable with the available water pressure in a minute's time. Sufficient phosphoric acid (chosen as a non-volatile acid) to dissolve the carbonate was introduced into the stoppered funnel with about

* Loc. cit.

50 cm.³ of water, which had been previously purified from carbon dioxide by boiling until one-third had been driven off in steam, and kept in full, stoppered flasks until used. The acid was then allowed to enter the boiling flask and the carbon dioxide driven over completely to the absorption flask by boiling for five minutes—the latter being shaken frequently during the passage of the gas into it and kept cool by standing in a dish of water. The atmospheric pressure was then restored by admitting purified air through the funnel of the boiling flask. In the experiments of Table I, the inlet tube of the absorption flask was closed by a rubber cap after disconnection, the exit tube was attached to potash bulbs and the flask was cooled in a stream of water. The exit tube was removed, a capillary tube long enough to reach below the surface of the liquid introduced and decinormal iodine run in until the large excess of barium hydroxide had been destroyed. Then the glass stopper of the absorption flask was introduced, with a rubber cap on the inlet tube and potassium iodide solution in the trap, as in standardizing, and the emulsion brought to a boil. Iodine was again run into the hot solution through the inlet tube until the color remained distinctly red after a second boiling. After cooling, the excess of iodine was determined by standard arsenious acid.

TABLE I.

	$CaCO_3$ taken grm.	BaO_2H_2 taken grm.	BaO_2H_2 found grm.	CO_2 found grm.	Error on CO_2 grm.	Error Corrected grm.
1	·0501	·2484	·1604	·0227	·0006+	·0007+
2	·0500	·2381	·1508	·0224	·0004+	·0005+
3	·1022	·3416	·1675	·0447	·0003−	·0001−
4	·1026	·3105	·351	·0450	·0001−	·0000
5	·2032	·6181	·2692	·0896	·0002+	·0004+
6	·2049	·5761	·2223	·0908	·0006+	·0008+
7	·5088	1·1301	·2606	·2232	·0007−	·0000
8	·5015	1·0804	·2245	·2197	·0010−	·0003−
9	1·0032	2·0125	·3004	·4394	·0020−	·0006−
10	1·0064	2·0702	·3538	·4405	·0023−	·0009−

In experiments 7, 8 and 9, the barium hydroxide solution was estimated by weight—in the others by volume. The calcium carbonate used was Iceland spar in the form of chips, but, though it was the best material available and considerably better than the best commercial calcium carbonate at hand, the test of drying below red heat and the igniting to the condition of caustic lime with a blow-pipe, proved it to be slightly

deficient in carbon dioxide. The observed correction of ·0014 grm. for each gram of the carbonate is applied in the last column of the table.

The low results of the larger amounts of carbon dioxide, in contrast to the higher results of the smaller amounts, point to some action of the iodine upon the precipitated carbonate. It would be natural to suppose that such action would be greater upon the carbonate precipitated from a cold solution, and this proved to be the case. For when barium carbonate, precipitated under the conditions of the analysis described, was treated with 10 cm.^{3} of iodine and boiled again, a loss of ·0044 grm. of iodine (corresponding to ·0008 grm. of dioxide) was found; but when barium carbonate was prepared by passing carbon dioxide through a cold solution of barium hydroxide until the presence of the acid carbonate was proved in solution by filtering a portion and boiling—thus insuring the complete destruction of the hydroxide—the precipitated carbonate, after filtering and washing, was acted upon by 10 cm.^{3} of iodine solution to such an extent that ·0253 grm. of iodine (corresponding to ·0044 grm. of carbon dioxide) disappeared. The obvious inference is, therefore, that the carbonate should be boiled before the addition of iodine in the process.

The experiments of Table II were made like those of Table I, excepting in the following points: first, an ordinary flask of about 300 cm.^{3} capacity, which fitted with a rubber stopper, was substituted for the more expensive ground stoppered absorption flask; secondly, the precipitated carbonate was boiled before adding any iodine; and thirdly, after iodine was added to a yellow color and boiled, a second amount of iodine was run in to a red color, but the mixture was not boiled again. By this treatment the iodine is kept from acting on the precipitated carbonate, at least to such an extent that the action is not appreciable, and from attacking the rubber stopper used; incidentally, it is kept from entering the trap, but one is used, nevertheless, to prevent contamination from the outside air. A separating funnel, reaching below the surface of the liquid, was found a convenient means of introducing the iodine without loss into the hot solution. A higher vacuum is required when the smaller flask is used, especially when large amounts of carbon dioxide are to be determined. A pressure of 200 mm. of mercury was found to be sufficiently low, and in no case did a flask of ordinary thickness and of 300 cm.^{3} capacity collapse at that degree of exhaustion.

TABLE II.

	$CaCO_3$ taken grm.	BaO_2H_2 taken grm.	BaO_2H_2 found grm.	CO_2 found grm.	Error on CO_2 grms.	Corrected Error grm.
1.	·5023	1·1385	·2851	·2190	·0020—	·0000
2.	·5056	1·1414	·2801	·2211	·0014—	·0006+
3.	1·0011	2·0712	·3704	·4367	·0038—	·0002+
4.	1·0030	1·8788	·1736	·4376	·0037—	·0003+

The calcium carbonate used in this test of the smaller apparatus was the purest commercial article available; the error applied as a correction in the last column (·0040 grm. on carbon dioxide for a gram of carbonate) was determined by five closely agreeing analyses of various amounts in the larger apparatus.

The process, beside being delicate, is fairly rapid—the average time for a determination being about three-quarters of an hour.

It only remains to thank Prof. F. A. Gooch for many helpful suggestions and kindly advice in this investigation.

ART. XI.—*The Opisthoteuthidæ. A Remarkable New Family of Deep Sea Cephalopoda, with remarks on some points in Molluscan Morphology ;** by A. E. VERRILL.

THE genus *Opisthoteuthis* was first described and illustrated by me from a species (*O. Agassizii*) dredged by Mr. A. Agassiz, on the "Blake Expedition" off Grenada, in 291 fathoms.†

A second, but more imperfect, specimen was dredged by the Albatross, in 1884, off New Jersey, in 1058 fathoms.‡

The most remarkable external features of the genus are the posterior position of the siphon, which is also directed backward, and the close union of the pedal web with the entire under surface of the body. Thus the eight arms together with the broad web, which extends nearly to their tips, form an extensive disk-like ventral foot, adnate to the inferior or ventral surface of the body and extending beyond it on all sides. (Figures 1, 2, 3.) This arrangement is analogous to the position of the foot in the limpets and chitons among Gastropoda. Like those forms, *Opisthoteuthis* must be essentially a creeping and clinging mollusk, though not exclusively so, for the presence of small lateral fins indicates that it can swim, more or less. The siphon appears to be too small to be used for efficient locomotion.

The adhesion of the arms and web to the body must prevent

* Abstract of a paper read before the National Academy of Science at Washington, D. C., April, 1896.

† Bulletin Mus. Comp. Zoology, vol. xi, p. 113, plates I and II, 1883.

‡ Trans. Conn. Acad. Sci., vol. vi, p. 408.

the free use of those parts as an umbrella-like swimming disk, as they are supposed to be used in *Cirroteuthis*, the nearest allied genus. It seems probable, however, that the creature could swim by means of an undulatory motion of the lateral borders of the pedal disk, as is done by certain planarians and by many tectibranch mollusks. The posterior position of the siphon naturally shows that the genital duct and intestine must terminate posteriorly, at its base, for in all other Cephalopoda these organs terminate at the base of the anteriorly situated siphon, where the outflow of water from the gill-cavity takes place. In the specimens described by me the viscera were too much decayed to be accurately described or figured.*

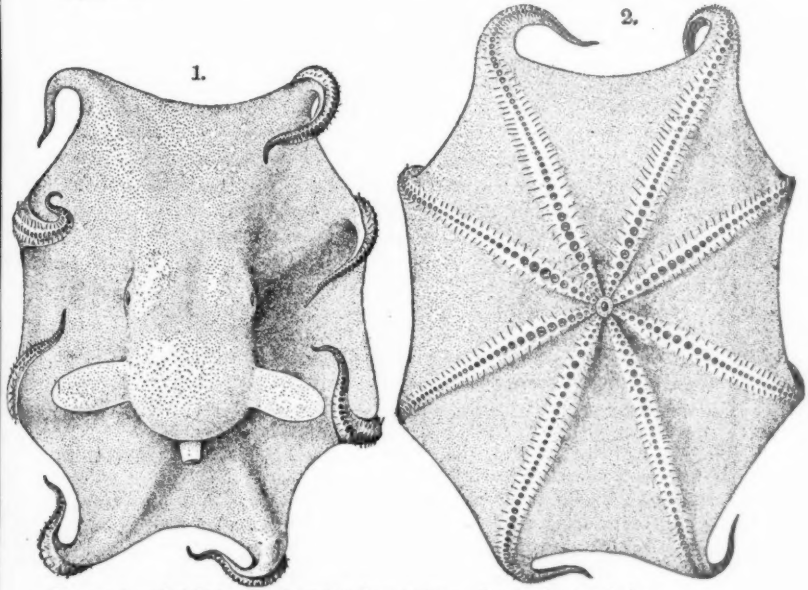


FIGURE 1.—*Opisthoteuthis Agassizii*, dorsal view. One-half natural size.
FIGURE 2.—The same, ventral view.

This deficiency has been supplied recently by a closely related Japanese species (*O. depressa*) described by Messrs. I. Ijima and S. Ikeda.†

This species was taken in 250 fathoms and was examined while quite recent. It adds another to the numerous instances

* This genus, like many other deep-sea cephalopods, etc., has a very soft gelatinous consistency and is difficult to preserve in alcohol unless the latter is kept ice-cold in an ice chest—a method not used at the time of these captures.

† Journal College Science, Imp. Univ., Tokio, vol. viii, pt. ii, 1895.

of closely allied deep water species occurring in Japanese and American waters. Their specimen was smaller than our own and the species differs in having smaller fins, a more depressed body, less prominent siphon, and some other characters, of no great importance.

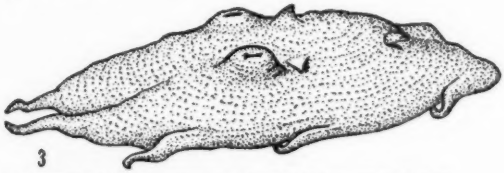


FIGURE 3.—*Opisthoteuthis depressa*, male, side view, natural size.

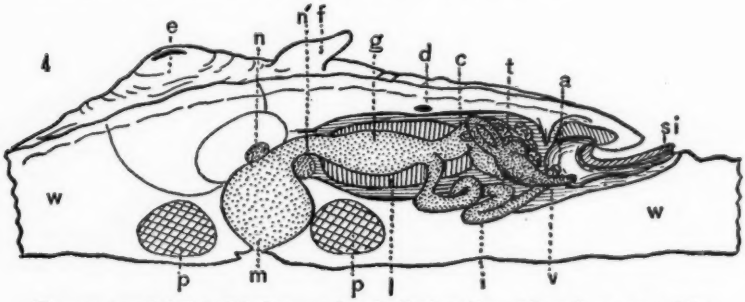


FIGURE 4.—*Opisthoteuthis depressa*, longitudinal section, enlarged. *e*, eye; *f*, fin; *p*, *p*, sections of arms; *w*, web; *si*, siphon; *d*, dorsal cartilage; *m*, mouth; *g*, stomach; *c*, cœcum; *i*, intestine; *a*, anus; *l*, liver; *t*, spermary; *v*, sperm duct; *n*, *n'*, cerebral and subœsophageal ganglions.

I have here reproduced some of their figures of the Japanese species. It will be seen by the sectional view (fig. 4) that the intestine passes directly backward, with only slight convolutions and without any forward bend, to the anal opening at the base of the siphon. There is a small cœcal appendage to the stomach. The pharynx has apparently no odontophore, which is also the case in Cirroteuthidæ, so far as examined. The jaws are after the usual cephalopod type. The reproductive organs (male) are posteriorly placed and the male duct (v) turns backward and opens at the base of the siphon. The gills (*b*, *b*, fig. 5) are short and have their apices turned backward. The gill cavity is partially divided by a median septum (s). The siphon is small and only slightly free from the pedal web at the tip. The gill opening is small and above the base of the siphon.

In the original description of this Japanese species the authors have made rather remarkable efforts, to reconcile the positions and relations of the parts with the theoretical,

strained, and as I believe, erroneous views of the orientation and homologies of the parts of cephalopods advanced by Huxley and still held by many other authors.

Thus they say that "the arched superior or posterior surface includes not only the posterior aspect of an ordinary cephalopod body but also the dorsal and ventral surfaces, as well as the outer surface of the umbrella. The head and body are thus flattened antero-posteriorly." According to their view, the siphon is "directed in the ventral, not in anterior direction, as is usually the case." They consider that "the ventral portion of the body is nowhere to be considered as concealed, except perhaps the mantle-rim, which is reflected inward at the branchial aperture. On the contrary, it stands, at least for the greater part, exposed more than ever, only with this peculiarity, that it forms a part of the general superior surface, thereby losing all definable boundaries from the real dorsal region or from the outer surface of the umbrella. Also that the original posterior end "is to be sought somewhere near the middle of the upper surface of the flattened body, behind the dorsal cartilage."

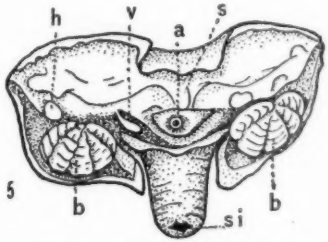


FIGURE 5.—The same as Fig. 3. Posterior view of gill cavity; *b,b*, gills; *h*, branchial heart; *s*, septum of gill cavity; *si*, siphon; *a*, anus; *v*, sperm duct.

The fact that such very unnatural and strained interpretations of the relations of parts have become necessary, ought to be sufficient to show that the theories on which they are based are erroneous. In fact, much of the interest connected with these forms consists in the fact that they throw much light on this very question of the relation of parts in the cephalopod body.

My own view of molluscan polarity is that the rudimentary cephalic ganglion which appears in the middle of the apical plate of the gastropod or bivalve larvæ, indicates the true anterior pole, while the mouth is behind the ventral edge of the apical plate, as in annelid larvæ. Later, by the progress of growth, the apical plate is reduced in size and the cephalic ganglions become more closely approximated to the mouth and œsophagus, so that the mouth may be considered as practically close to the anterior pole. The shell-gland, I think, may be taken to

indicate the position of the posterior pole, though many writers consider it as dorsal, being influenced by the position of the anus. The latter is formed later than the mouth and shell-gland and is too variable in position and mode of origin to be of much significance in this connection. Its normal and usual position in the larvæ is ventral, posterior to the mouth.

The theory adopted by Huxley, Lancaster, and many others,* that the actual *dorsal* surface of a cephalopod is the anterior region; that the actual *posterior* end of the body is the dorsal side; and that the actual *ventral* side is the posterior surface, I consider as entirely erroneous and without any real foundation. One of the fundamental errors that has led to this theory is the wrong interpretation of the gastropod body. Thus Lancaster took the specialized flattened form, seen in limpets and chitons, as the normal or primitive form, and therefore made the long axis of the foot the antero-posterior axis of the body. When discussing the more common and more normal forms, with a body prominent above the foot, whether spiral or not, he called the actual body the "visceral hump" and treats it as a sort of hump, or dorsal appendage of the body. Hence, should it stand nearly at right angles to the foot, its front surface would become anterior and its back or ventral surface would become posterior. The same erroneous reasoning would naturally compel the ordinary cephalopod (fig. 6) to stand on its head (the arms or pedal organs being placed around the mouth), and in that position the body would correspond to the "visceral hump or dome" of the gastropods. In view of all that is now known of the embryology, anatomy, and homologies of the mollusca, such theories seem to me quite untenable. To me the more natural and correct view appears to be to consider the *foot* as a ventral appendage, and the "visceral dome" of a gastropod as the true *body*, whether it be high or low, flat or round, straight or twisted, and regardless of the position of the anal pore.†

That this is the true view can be easily shown by the study of the development of the larva in the proveliger‡ and veliger stages, for the larva early acquires definite anterior and posterior ends, and dorsal and ventral surfaces are differentiated

* This view is adopted and discussed at some length in the recent Text-Book of Comparative Anatomy, by Dr. Arnold Lang, 1896.

† The anus is variously situated in gastropods that have the shell small or abortive, though the normal position is at one side of the neck-region in the gill-cavity, when a spiral shell is present, because the gill-cavity must necessarily be anterior in such cases. Huxley regarded the mouth and anus as representing respectively the "true morphological" anterior and posterior poles of the body. This view when applied to the various positions of the anus in Opisthobranchs, leads to very strange results.

‡ The stage that I call *proveliger* is that which precedes the formation of the functional anal pore and complete intestine, but in which the shell-gland is present. The subveliger is the next stage; in this the true shell begins but the intestine is still incomplete.

before the foot appears. The latter first arises as a small *ventral* protrusion, between the mouth and anus, which are very near together, in the subveliger stage of nearly all gastropods and bivalves.

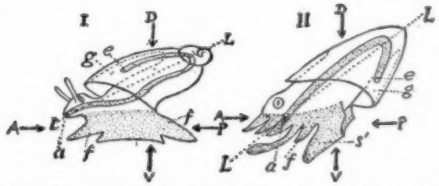


FIGURE 6.—Diagramatic figures, to show axes. I, gastropod; II, cephalopod; A, P, longitudinal or antero-posterior axis, D,V, dorso-ventral axis, according to Lancaster; L,L, longitudinal axis as understood by the writer; *a*, mouth; *e*, anus; *g*, gill cavity; *f*, foot; *s'*, siphon. (Copied from Lancaster with addition of lines L,L.)

Taking this as a true exposition of the relation of parts in a gastropod, it is easy to prove that the body of a cephalopod corresponds to that of a gastropod, and that the actual dorsal is the true dorsal side; that the pedal organs (arms, web, siphon) are anterior and antero-ventral in all ordinary adult forms;* and that the intestine makes a sharp turn and terminates in the median line, below the neck, at the base of the siphon, † and, therefore, behind the antero-ventral foot, which, indeed, is the primitive position in the larval state of most mollusca, and may, therefore, be called the *normal* position.

In *Opisthoteuthidæ*, on the contrary, the siphon and branchial cavity have been pushed backward to the posterior end of the body, far away from the mouth, owing to the peculiar development of the arms and web and their extensive union with the ventral surface of the body. The intestine has, therefore, lost its usual forward bend. Thus the family, in these respects, stands in about the same relation to other cephalopods that chitons do to ordinary gastropods.

These peculiarities seem quite sufficient to warrant the forming of a new family group. The Opisthoteuthidæ agree with the Cirroteuthidæ in having a single row of suckers on each arm, with two lateral rows of slender cirri; in having a broad web; in the presence of lateral fins; and, apparently, in lacking an odontophore.

The exceptional positions of the anus, siphon, gills, sexual and renal organs, in this family, make it agree, in these respect, with Lancaster's hypothetical "arche-mollusc."‡ However, in

* In the embryo (squids, etc.,) the arms arise below and behind the mouth and only surround the oral disk at a later period.

† The two folds that arise on each side of the embryo and finally unite to form the siphon are regarded as lateral parts of the foot.

‡ Encyclop. Brit. vol. xvi, p. 615. It should be stated that Lancaster, himself, does not claim that his "schematic mollusc" or "archetype" is such in the sense of a real primordial ancestral mollusk.

this group, this can only be regarded as an extreme secondary modification, due to a high degree of specialization connected with the adoption of a creeping and clinging mode of life, analogous to that of the chitons and limpets. It certainly cannot be regarded as a survival of a primitive arche-molluscan condition. It is not probable that the analogous positions of the organs in the chitons should be considered as arche-molluscan, or as proving that such were the original positions of parts in the ancestral forms of all mollusca. The chitons themselves are peculiarly specialized forms of gastropods, adapted to a special mode of life, and therefore cannot be considered as very primitive. Moreover, normal gastropods, so far as known, appeared earlier than chitons in geological time. Chitons are sparingly represented in the Lower Silurian, but normal gastropods are common in the Lower Cambrian, associated with the earliest forms of life yet known.

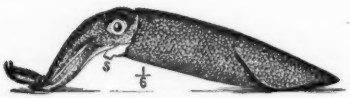


FIGURE 7.—*Loligo Pealei* in its natural position, at rest, from life. One-sixth natural size.

FIGURE 8.—*Octopus Bairdii*, young male, at rest, from life; *b*, hectocotylized arm.

The real arche-mollusca were far more probably similar to the simpler forms of gastropod and pteropod proveligers and veligers and, like these, free-swimming forms.

It is probable that many of the early cephalopods, such as *Orthoceras* and allies, having a long and very unwieldy shell, with a comparatively small last chamber, were not capable of swimming, but were either nearly sessile, and lived with the shell more or less buried in the mud, or else dragged the shell slowly over the bottom. The same was probably true of the irregularly curved forms, both of the Nautilacea and Ammonacea. Such forms would, however, have had active swimming young, perhaps of the veliger type, as a necessity for their wide dispersion.

The recent discovery* that *Conularia* was sessile and attached at the apex, renders it probable that the genus belongs to the Cephalopoda, when its other characters are also considered. It is probable, in that case, that it represents a very primitive group, in which the initial secretion of the shell-gland of the veliger-like young served for attachment. As the group cannot be referred to any recognized order or suborder, it may be designated as *Conulariacea*. It may, very likely, have been an ancestral form of Dibranchiata.

* R. Ruedemann, Amer. Geologist, vol. xvii, p. 158, March, 1896.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The fusibility of platinum in a blast-furnace fed by carbon.*—The oft-repeated assertion that platinum can be fused in a furnace fed with carbon and air has been subject to some doubt on account of the possibility of the contamination of the metal by carbon or other substances in the furnace. Victor Meyer has now succeeded in melting the metal when enclosed in a thick block of refractory earth in such a manner that no impurities were taken up. The fuel used was retort carbon broken up in pieces of the size of a hazel-nut, and the air was supplied by a powerful blast. An alloy of 75 parts of platinum and 25 parts of iridium, exposed to the same temperature in another cavity of the same block of refractory material, remained entirely unaffected.—*Chem. News*, lxxiii, 235. H. L. W.

2. *The condition of the water in analcite.*—In making an analysis of analcite of peculiar form and optical properties Charles Lepierre has taken occasion to determine the temperatures at which the water is given off. He found that it lost almost exactly half its water upon long heating to constant weight at 200°, and that this loss was not increased at 300°. At 440°, however, all of the remaining water was disengaged. The higher temperatures, 300° and 440°, were obtained by the use of the vapors of a high-boiling petroleum-product and of sulphur respectively, so that these temperatures may be regarded as reliable. The author believes that his results indicate that the formula representing the composition of the mineral is much simpler than that proposed by F. W. Clarke, since according to the latter formula the water would not be expected to be given off in two equal parts. He proposes the formula $H_4Na_2Al_2Si_4O_{14}$, and develops it in such a manner that four hydroxyl groups are attached to the silicon atoms.—*Bull. Soc. Chim.*, III, xv, 561. H. L. W.

3. *Quantitative separations by means of hydrogen peroxide.*—During the past five years Jannasch and his pupils have studied a number of separations based upon the oxidizing action of hydrogen peroxide, usually in alkaline solution. The reactions utilized are chiefly the precipitation of manganese, lead and bismuth as peroxides, and the oxidation of chromium compounds to chromates. The peroxides are precipitated in most cases by pouring the moderately acid solution of the salts to be operated upon into a mixture of an excess of ammonia and hydrogen peroxide with continual stirring. In the case of lead and bismuth the operation is performed in the cold, while with manganese the whole is warmed for a short time to cause the precipitate to settle. Separations are thus made from zinc, nickel, cadmium, mercury, silver and copper. In the separations from arsenic sodium hydroxide is used in place of ammonia, and in some instances the separation is

made in the presence of potassium cyanide. Many of the separations must be repeated in order to attain completeness. The peroxides dissolve with great readiness in a mixture of nitric or hydrochloric acid and hydrogen peroxide, the latter reagent acting in this case as a powerful reducing agent. A serious difficulty with this method arises from the presence of impurities, especially silicic acid, in commercial hydrogen peroxide. The reagent can, however, be obtained in a pure condition by distillation, according to Wolffenstein's method, under diminished pressure.—*Zeitschr. anorg. Chem.*, xii, 134, etc. H. L. W.

4. *The use of "heavy solutions" in the examination of commercial fertilizers.*—Thoulet's solution, which has been so extensively used by mineralogists, has been applied by A. P. Bryant to the separation of mineral phosphates from phosphates existing in the form of bone, tankage, etc. Heretofore there has been no means of distinguishing the cheaper "rock phosphates" from the "organic phosphates," which are undoubtedly more readily available as food for plants, as they occur in prepared fertilizers as sources of "insoluble" phosphoric acid. The author uses a solution of specific gravity 2·26, and gives the following table of the specific gravities of substances commonly occurring in the materials under consideration:

Bone and other organic matter, less than	2·0
Gypsum	2·3
Aluminium phosphates	above 2·3
Iron phosphates	about 2·6
Silica	2·65
Calcium phosphates	2·9 to 3·55
Fluorite	3·2

The separation is applied after treatment with water and drying, but before extraction with ammonium citrate. The simple apparatus recommended by the author consists of a plain glass tube about $1{\cdot}3^{cm}$ in diameter and 20^{cm} long, which is attached by means of a short piece of rubber tubing to a tube of the same diameter about 7^{cm} in length and closed at the end. The material is placed in this apparatus with the heavy solution, and, after corking, is thoroughly agitated. After the liquid has become perfectly clear the rubber tube is closed with a pinch-cock and the two portions are washed and submitted to analysis. A number of test-experiments, made with mixtures of known origin, gave extremely satisfactory results.—*Jour. Am. Chem. Soc.* xviii, 491. H. L. W.

5. *The action of nitric acid upon potassium cobalti-cyanide.*—In attempting to produce compounds analogous to the nitroprussides by the action under consideration, Jackson and Comey, while failing in this attempt, have obtained an interesting, new class of salts. By long-continued boiling of potassium cobalti-cyanide with strong nitric acid, the liquid gradually became dark red and finally suddenly changed to a semi-solid gelatinous mass.

After drying in a vacuum the substance showed the composition corresponding to the formula, $KH_2Co_3(CN)_{11}.H_2O$. The substance, after drying, slowly dissolves in water at 60°, but leaves only a varnish upon slow evaporation. The solution gives precipitates with the salts of most of the metals. The silver and barium salts, thus produced, gave results upon analysis corresponding to the formula $Ag_2Co_3(CN)_{11}.H_2O$ and $BaHCo_3(CN)_{11}.1\frac{1}{2}H_2O$.—*Berichte*, xxix, 1020. H. L. W.

6. *The substitution of various substances in the place of the water of zeolites.*—GEORGES FRIEDEL has shown that the water of certain zeolites can be replaced by ammonia. He found also that hydrogen sulphide is absorbed with great energy by dehydrated chabazite and harmotome, giving, after long exposure to the gas, an increase in weight greater than that of the water lost. The product lost hydrogen sulphide when exposed to the free air, taking up water and returning to its original condition. Carbonic acid acted with the same species in the same way. Ethyl alcohol was absorbed slowly but abundantly. Hydrogen was condensed by them very rapidly, but its loss was so rapid that no accurate weights could be made. Finally the author has made an observation which is of great importance to the analytical chemist, viz: that atmospheric air is absorbed so abundantly as to render inexact the determination of water by simple loss by ignition, at least unless fusion takes place. Chabazite absorbed in a desiccator in a few minutes a quantity of air amounting to 1·77 per cent of its weight. The presence of this air was easily shown by putting the dehydrated material in a tube filled with mercury, then adding a few drops of water, when the crystals fell to powder and discharged a large volume of gas. This air when analyzed showed the existence of only about 8 per cent of oxygen, and it was, therefore, very different in composition from ordinary air.—*Compt. Rend.*, cxxii, 1006. H. L. W.

7. *Elementary Treatise in Electricity and Magnetism*, founded on Joubert's "Traité Élémentaire d' Électricité," by G. C. FOSTER and E. ATKINSON, 552 pp., London, New York and Bombay, 1896 (Longmans, Green & Co.). — The Elementary Treatise of Joubert is well known for its highly clear and systematic presentation of the fundamental principles of electricity and magnetism. This excellent work is now made available for the use of the English-speaking public in general, and in accomplishing this the editors have performed an important service to English and American students. The present work is, however, more than a translation, for the English editors have to some extent modified the method of presentation, in particular as regards the introduction of the method of viewing electrical phenomena originated by Faraday and developed by Maxwell. They have thus throughout made use of the conception of lines and tubes of force, also of the charge of an electric field as a whole rather than that of the conductors on whose surface the charge appears. They have also simplified the work for the

elementary student by giving in certain cases the successive steps of the mathematical discussions in greater detail, so that the whole reasoning can be more easily followed.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following portions of the 16th annual report, 1894–95, have appeared*:

Public Lands and Their Water Supply, by F. H. Newell, Part II, pp. 459–533, pls. 5. Now that the humid public lands have been disposed of, and practically one-third of the total extent of the United States (not including Alaska) semi-humid and arid, is still vacant, it becomes necessary to know its water supply in order to determine the conditions of prosperous development. The report contains a map showing the relative location of forests, woodlands and irrigated areas, and it is gratifying to know that the appropriations for this work, which must furnish the information for the intelligent administration of public lands, is increasing.

The other papers of Part II of the 16th annual, lately issued and completing Part II, are:—

Geology of the Cripple Creek Mining District, Colorado, by Whitman Cross and R. A. F. Penrose, pp. 1–209.

Geology of Road Building Stones of Massachusetts, by N. S. Shaler, pp. 283–328.

Geology of the Mercur Mining District, Utah, by J. E. Spurr, pp. 344–454 (abstract this Journal, IV, vol. i, p. 395).

Water Resources of a Portion of the Great Plains, by Robert Hay, pp. 535–588.

The following Bulletins have appeared recently:

The Disseminated Lead Ores of Southeastern Missouri, by Arthur Winslow, Bull. 132, pp. 31, pls. 6, 3 colored maps and sections. This report is an explanation of the work published in vols. vi and vii of the present State Geological Survey of Missouri.

Contributions to the Cretaceous Paleontology of the Pacific Coast: The Fauna of the Knoxville Beds, by T. W. Stanton, Bull. 133, p. 132, 20 pls. (abstract this Journal, IV, vol. i, p. 320).

The Cambrian Rocks of Pennsylvania, by C. D. Walcott, Bull. 134, p. 43, pls. 15. This paper records observations made during the summer of 1892 and 1893 upon the belt of Lower Paleozoic rocks and contains a map showing the distribution of the Cambrian, Silurian and Mesozoic strata in the southeastern portion of Pennsylvania. On page 33 Mr. Walcott says that "The discovery of the Olenellus or Lower Cambrian fauna in the Reading sandstone practically completes the correlation of the South Mountain, Chickies, and Reading quartzites, and establishes the correctness of the early correlations of McClure, Eaton, Emmons, and Rogers. They all considered the basal quartzite as the same

* Six papers in pt. I of the 16th annual are yet to appear.

formation from Vermont to Tennessee." "The superjacent limestones carry the Olenellus fauna in their lower portions in northern and southern Vermont, eastern New York, New Jersey and Pennsylvania. To the south of Pennsylvania the lower portions of the limestones appear to be represented by shales, and the Upper and Middle Cambrian faunas are found in the lower half of the Knox dolomite series of Tennessee, and they will probably be discovered in the same series in Virginia and Maryland when a thorough search is made for them. The same may be predicted, but with less assurance, for the northern belt of limestone crossing Pennsylvania into New Jersey, as the limestones between the Olenellus zone and the Trenton zone represent the intervals of the Middle and Upper Cambrian and the lower Ordovician, or the Calciferous and Chazy zones of the New York section. The working out of the details of this section in southeastern Pennsylvania is an interesting problem left for solution to some geologist who has the necessary paleontologic training, and who will not be discouraged by the prospect of a good deal of hard work before the desired result can be obtained."

"The problem of where to draw the line in this series of limestones, on a geologic map, between the Cambrian and Ordovician, is one that will seriously embarrass the geologist, but I anticipate that either lithologic or paleontologic characters will be discovered by which the two groups can be differentiated."

The final seven pages and six plates are devoted to the consideration of intraformational conglomerates,—that is, of conglomerates "formed within a geologic formation of material derived from and deposited within that formation." In explaining their origin, Mr. Walcott believes that the sea bed was raised in ridges or domes above sea level, and thus subjected to the action of shore ice, if present, and the ærial agents of erosion.

The following are the FOLIOS which have been recently issued:

No. 21. Pikesville, Tenn., lat. 85°–85° 30′, long. 35° 30′–36°, by W. C. Hayes.

No. 22. McMinnville, Tenn., lat. 85° 30′–86°, long. 35° 30′–36°, by W. C. Hayes.

No. 23. Nomini, Md. & Va., lat. 76° 30′–77°, long. 38°–38° 30′, by N. H. Darton.

No. 24. Three Forks, Mont., lat. 111°–112°, long. 45°–46°, by A. C. Peale.

No. 25. Loudon, Tenn., lat. 84°–84° 30′, long. 35° 30′–36°, by Arthur Keith.

Crater Lake, (Oreg.), Special Topographic Sheet with illustrations and geologic text on back, by J. S. Diller.

2. *American Paleontology Prize.*—A prize of fifty dollars is offered by Prof. G. D. HARRIS, editor of the Bulletins of American Paleontology, for "the best American (North, Central or South) paleontological article presented for publication, as a separate bulletin, before May 1, 1897. The article must be a well

written original monograph or report upon some special problem studied in the field or laboratory or both, i. e., not a mere compilation from books. This report may contain from 50 to 200 pages and from 5 to 10 full page plates of the size of the bulletins. It may be written in any language using Roman characters. The judges in awarding the prize shall have the power to divide the prize in two equal parts in case of doubt between the merits of two excellent articles, or to withhold the prize in case no suitable article appears. All communications regarding the matter should be addressed to Prof. G. D. Harris, Department of Paleontology, Cornell University, Ithaca, N. Y. H. S. W.

3. *The Midway Stage*, by G. D. HARRIS (Bull. Am. Pal., No. 4, Ithaca, N. Y., June 11, 1896, pp. 1–156, plates 1–15).—This fourth number of Professor Harris' Bulletins discusses, in the author's thorough way, the formations and fossils of the lowest midway stage of the Eocene in the Southern states.

In the course of the paper the author has shown that there is unconformity between the Cretaceous and overlying Eocene east of the Mississippi, and a contact between the two is photographed in Plate II.

The author's study of the species examined leads him to the following conclusions, as summarized in a communication received from him.

"All of Gabb & Safford's 'Ripley Cretaceous' fossils from Hardeman Co., Tenn., are Eocene.

"The uppermost 100 ft. of Smith & Johnson's 'Cretaceous' section at Prairie Bluff is Eocene, as proven by an abundant and typical Eocene fauna.

"The beds at and to the south of Palmer's mill, Wilcox Co., Ala., referred to the 'Cretaceous' by Smith & Johnson (Bull. 43, U. S. G. S.) are all Eocene. Here, as on the Alabama River, they have their contact line 100 or more feet too high.

"*Euclimatoceras ulrichi*, instead of being confined to one calcareous bed, a few feet in thickness, is now known to occur in every important bed of the Midway stage in western Alabama, from the contact (Cret.–Eoc.) below to and including the Matthews landing horizon.

"The Chattahoochee River Midway limestones are the representatives of the whole Midway stage to the west, and are not the outgrowth of an insignificant rock in western Alabama."

The paleontological part of the work gives the description, figures and synonomy of all the well authenticated species of the Midway stage and of forty-five new species and several varieties. The genera *Perna*, *Isocardia* and *Keilostoma* are reported for the first time from North American Eocene deposits. H. S. W.

4. *The Student's Lyell, a Manual of elementary Geology*, edited by JOHN W. JUDD, pp. 635, figs. 736. London, 1896. (John Murray.)—This once standard student's manual of geology is presented with corrections and additions, the latter particularly in the way of illustrations of newly discovered fossils, but retaining the

chief characteristics of the author. The application of the term *Epigene* to include both aqueous and volcanic rocks, in contrast to the plutonic igneous rocks to which Lyell gave the name *Hypogene*, shows how modern science has already gone beyond the theories of the great master. We observe a few paragraphs in which the progress of science and even political classification in the United States are disregarded. Thus "Freshwater strata of western territories" and "greensands of New Jersey" give a very inadequate notion of the present knowledge of the "Cretaceous" in North America (p. 336). The same remark applies to "Limestones and shales of the Appalachians" as the only indication of the American representative of the lower Carboniferous (p. 395). We notice (p. 431) that the "Calciferous sandstone" is made to be the equivalent of the upper division of the Cambrian; and the earliest trace of fishes is described as "(?) Ordovician, California," which probably refers to the Cañon City, Colorado, beds. Many valuable additions are made in the way of illustration to the 1871 edition of "The Student's Elements of Geology" which formed the basis of the present volume. H. S. W.

5. *Chloritoid from Michigan—a Correction*, by Wm. H. Hobbs. (Communicated.)—In a paper published in this Journal (vol. l, p. 121, 1895, I mentioned the occurrence of a mineral in blocks on the south side of Michigamme Lake, Michigan, and gave sufficiently full chemical and optical data to determine it as chloritoid. Since the paper was published Dr. A. C. Lane has called my attention to the fact that the chloritoid of this locality is probably nearly or quite identical with that of the Champion Mine described by Kellar and Lane in this Journal (vol. xlii, p. 499). A more careful examination of the mineral shows that it is certainly triclinic as determined by Lane, the most important evidence of this being the fact that prismatic sections which exhibit the deep blue absorption of b have extinction angles with the base of 20° or more. Figure 6 of my paper, which is drawn to represent an approximately monoclinic mineral, is therefore incorrect as regards the crystallographic orientation. I should also add that on page 31 of the fifth volume of the Geological Survey of Michigan a reference is made by Rominger to the occurrence of chloritoid in loose blocks south of Michigamme village. This volume was issued shortly before my paper, but my efforts to secure a copy had been unsuccessful.

In a paper published as a bulletin of the University of Wisconsin (Science Series, vol. 1, No. 4, p. 140) in enumerating the several types of marcasite from the ore deposits of southern Wisconsin and northern Illinois, one type (type 2) was mentioned which was supposed, from the direction of apparent indistinct striations on the base, to represent a tabular type bounded on the long edge by the macropinacoid. The crystals were very imperfect and almost completely altered to limonite. Subsequent examination of similar but better specimens from the same locality reveals the fact that this type is produced by the distortion of twinned individuals, the face marked *a* in the figure being not the macropinacoid but the prism.

6. *Report of the Section of Chemistry and Mineralogy*, by G. C. HOFFMANN. Part R, Ann. Rep. Geol. Surv., Canada, 1896.—This report, which is largely devoted to technical analyses and assays, the analyses being chiefly of a series of marls, contains, however, some notes of general interest on the occurrence of minerals in Canada. We note the following:

(1.) Celestite occurs in a vein two feet wide cutting limestone in the township of Lansdowne, Leeds Co., Ontario. Is at times quite pure, though often associated with calcite and galena. Colorless, sometimes pale bluish or reddish, semi-transparent: crystalline, though distinct crystals are not mentioned. An analysis by Mr. R. A. A. Johnston gave:

SrO	BaO	CaO	SO_3
56·31	*tr.*	0·11	43·51 = 99·93

(2.) Tetrahedrite containing lead, from the Antelope claim Kaslo Slocan camp, West Kootanie Dist., Brit. Col., occurs associated with galena, sphalerite, pyrite and quartz. Massive, iron-gray in color. Sp. gr. 5·08. Analysis by Mr. R. A. A. Johnston, after deducting quartz, gave

Sb	As	Cu	Ag	Pb	Zn	Fe	S
28·22	·23	22·14	11·20	9·38	6·22	·93	21·68=100·00

(3.) Leucite occurs in smoke-gray, sub-translucent crystals up to 2·5^{cm} in diameter, embedded in a dark gray rock which was found as bowlders in the auriferous gravel of the Horsefly Mine on Horsefly River about seven miles above its entry into Quesnel Lake, Cariboo Dist., Brit. Col. L. V. P.

7. *Les Mines d'Or du Transvaal*, par L. DE LAUNAY. 8°, 540 pp., 11 pl., 81 fig. Paris, 1896 (Baudry & Cie).—The great prominence that the gold mines of the Transvaal region have assumed in the past few years, due to their great extent and wonderful richness and to the political complications to which their wealth has led, renders the appearance of this work especially well-timed.

The first portion of the book is devoted to a general description of the country, the climate, productions, means of communication, a description of the chief towns, its history and a very full account is given of the organization of the mining industries from financial, legal and economic or industrial standpoints. The second part comprises a geological account of the ore deposits, their origin and method of occurrence, while a third portion describes the methods of mining, the treatment of the ores and the various metallurgical processes employed. In conclusion the author gives in a general résumé the present state of the mining industry and its probable future.

As the work is well illustrated and written in a style that is neither too technical nor judicially severe, it will prove of value not only to the scientific expert and mining engineer, but to that portion of the general public as well who are interested in the region. L. V. P.

8. *Lehrbuch der Ökologischen Pflanzen-geographie*, von Dr. EUGEN WARMING. Berlin, 1896, pp. 412.—Professor Warming, of Copenhagen, has presented in this interesting work some of the more important facts regarding the relations of plants to their surroundings. The adaptations of vegetation are classified in a simple manner which gives the impression of an exhaustive system. All the factors are considered in turn and the response of plants to all external influences is stated clearly. Mutual relations of plants and animals are taken up in a very attractive and thorough fashion, and without any attempt at exaggeration. The biological associates are properly grouped and described, and, lastly, the struggle between these groups is dealt with in a graphic style. This contribution to geographical botany merits an early and good translation into the English language.

G. L. G.

9. *Missouri Botanical Garden. Seventh Annual Report.* St. Louis, Mo., 1896, pp. 209.—Professor TRELEASE gives a valuable monograph on the Juglandaceæ of the United States in which he has tabulated characters presented by the fruit, twigs, bark, and buds. He states that, owing to the publication of the seventh volume of Professor Sargent's Silva of North America, he does not consider it desirable to publish the entire manuscript he had prepared. Even in its abbreviated form it is a very important addition to the literature of the subject. It is characterized throughout by the excellent qualities which mark all of Professor Trelease's work.

From Miss Mulford we have a careful study of the Agaves of the United States. The histological and economic aspects of these plants have received much attention from her, and are here clearly described.

Mr. C. H. Thompson treats of the ligulate Wolffias of the United States.

The Director presents an interesting account of the pre-Linnæan library presented to the Garden by Dr. E. Lewis Sturtevant of Massachusetts. This exceedingly valuable library will be of the greatest use in the researches in regard to cultivated plants which are prosecuted under Professor Trelease's direction. G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The height of the luminous night-clouds.*—The Observatory at Berlin is about to publish the results of an elaborate investigation of the luminous night-clouds by Dr. Jesse. The author gives in the Astronomische Nachrichten, No. 3347, some of the principal results of his observations and discussion. They are based on photographs taken in the months of June and July in the years 1889–91 at Steglitz, Berlin, Nauen and Rathenau. A striking peculiarity of the results is the almost constant altitude of the clouds. Although the photographs were not strictly simultaneous, yet the computed heights of points in these clouds lie between 80·27 and 88·53 kilometers, the mean height of the series being 82·08.

2. *Publications of the Washburn Observatory of the University of Wisconsin*, vol. ix, pp. 258, 4to, Madison, 1896.—This volume contains, 1st, the results of an elaborate investigation of the aberration and atmospheric refraction by Prof. Comstock, and 2d, observations of the right ascension of certain stars made by Mr. Flint with a prism apparatus.

3. *Mathematical papers read at the International Mathematical Congress held in connection with the World's Columbian Exposition, Chicago*, 1893, 8°, pp. xvi, and 411. New York, 1896. (Macmillan & Co. for the American Mathematical Society: $4.00).—This volume is vol. i of papers published by the Am. Math. Soc., the society having given $600 towards its publication. It is edited by a committee of the congress of which Prof. E. H. Moore was chairman, and it contains forty-five papers furnished by American, German, Swiss, Austrian, French and Russian mathematicians. With such a wide circle of contributors the volume naturally covers subjects of widely varied character. It is, of course, a volume that must find place in every university library.

4. *American Association for the Advancement of Science.*—The forty-fifth meeting of the American Association is to be held in Buffalo, N. Y., from August 22d to 29th. The preliminary program, recently issued by the permanent secretary, F. W. Putnam, gives the places and times of meeting, statements as to excursions and so on. Mr. Putnam's address is Salem, Mass., until August 17th, after that, A. A. A. S., Buffalo; the address of the local secretary is Mr. Eben P. Dorr, A. A. A. S., Buffalo.

5. *The British Association for the Advancement of Science.*—The sixty-sixth meeting of the British Association is to be held at Liverpool, from September 16th to 23d.

6. *Journal of Physical Chemistry.* — The attention of the readers of this Journal is called to the prospectus inserted in the present number of the new *Journal of Physical Chemistry*, the publication of which is to be commenced at Ithaca, N. Y., under the editorship of Professors Wilder D. Bancroft and Joseph E. Trevor. It merits the cordial support of all interested in this department of science.

Obituary.

Joseph Prestwich, the distinguished English geologist, died in June at the age of eighty-four years.

M. Daubrée, the eminent French geologist, died at Paris on May 29, at the age of eighty-two years. His long life bore abundant fruit and gave him a foremost place among the workers in science, not only in his own country, but in the world at large. His researches were numerous, and of the highest value; they covered a wide field, embracing particularly experimental geology, the artificial production of minerals and the characters of meteorites. Those who had the privilege of his personal acquaintance will never forget the peculiar charm of his courtly, genial manner, which expressed his high character and kind, generous heart.

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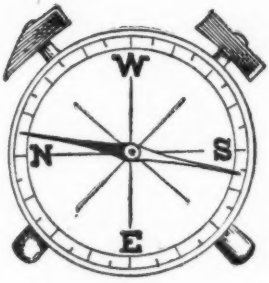

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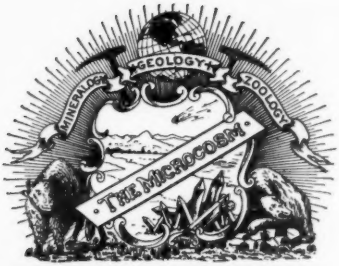

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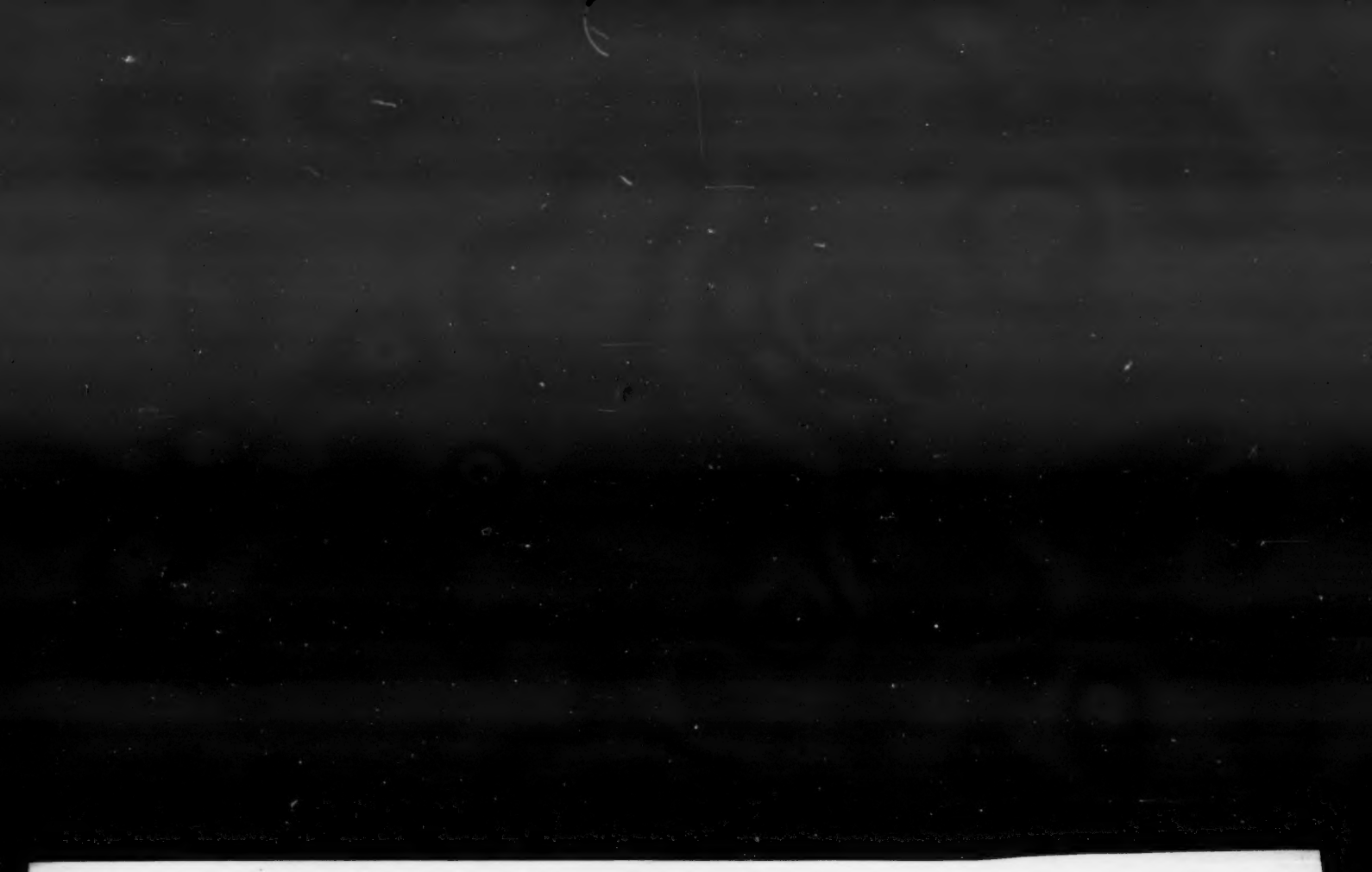
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